HOUSE ORGAN OF Q-ALLOYS "To Be Sure" GENERAL ALLOYS COMPANY

# ALLOY PROGRESS

EDITED BY [signature] PRESIDENT

Bright Spot in Metal Progress

ENTIRELY ABOUT HEAT & CORROSION RESISTANT ALLOY CASTINGS

VOLUME IV NUMBER 4

# Write Your Own Title

THE most superb caricature I have ever seen greets your eye, Pondering Pup and Panting Lion.

This compelling picture, significant beyond words, stimulated thought in concentric ripples, like a stone cast in a mill-pond. Ripples that widen into deep philosophic thought, as I strive to strain that thought thru these stubborn keys.

Youth and Age, both in caricature, as each appears to the other. The "Old Fogey" and the "Young Pup." Extremes, of course, but between such "extremes" runs the path we tread from the Cradle to the Grave.

You fit, gentle reader, between the Pup and the Lion. Between the quick and the dead. You look with scorn at one, with sympathy at the other, unless you have a gift of understanding.

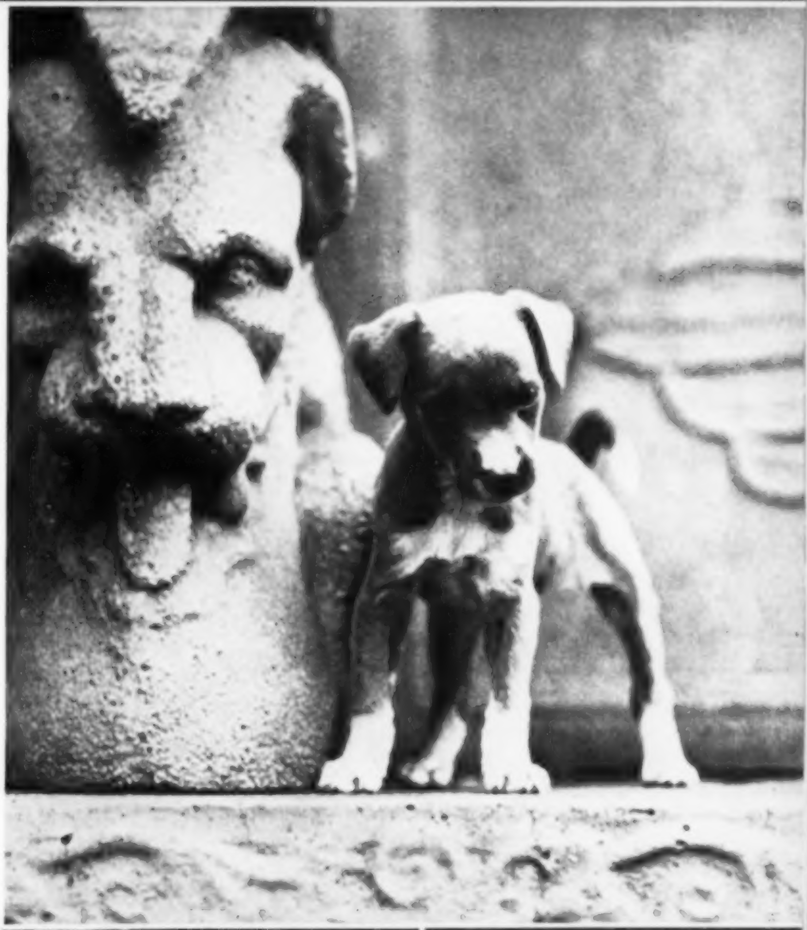
Between these extremes of curiosity and satiation, of germination and petrification, of wisdom and ignorance, lies life, strife and the fertility or futility that marks our passing.

It is ever thus with life or progress. The hot ones going in heat, the cold ones coming out, just the reverse of those Q-Alloy boxes in a counterflow carburizer. I could write a hundred titles to this picture, many humorous, some pathetic, some prophetic, they crowd into my mind and want to overrun this paper. "Youth and Seniority in the Corporation,"—that picture's a fair organizational diagram of many organizations, with the SOBS in the middle left out. Not "Murphy and Statesmanship," or the "Constitution and the New Deal," or "The British Lion and The Duke," or "Lewis and Green," those titles are *too realistic*.

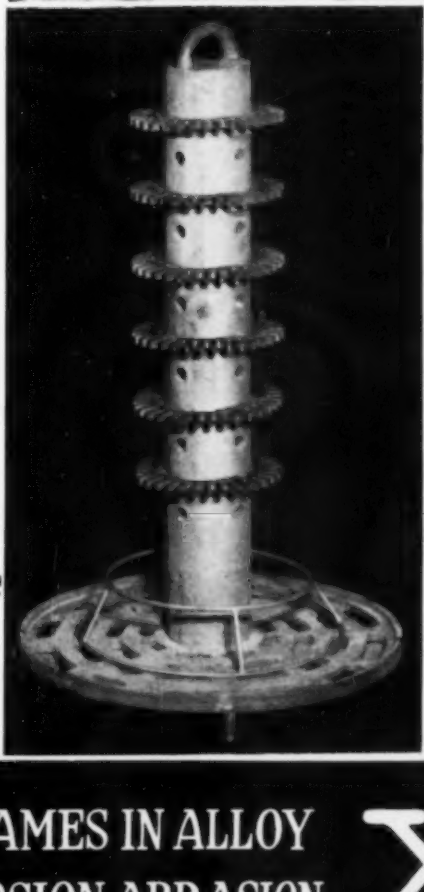
I wonder what Ben Fairless and Paul Voigt would title that picture. Whatever vitality you credit to the pup, the lion sure has a cold nose. I wonder what they're thinking? Maybe the Pup is hoping he'll grow up to be whatever he thinks the lion is,—which he probably isn't,—and Leo, perchance, is pensively humming to himself, "Pray turn, oh turn backward, Time in your flight, and make me a pup again just for tonight." Here is Youth and Age, as each sees the other, and they are both wrong.

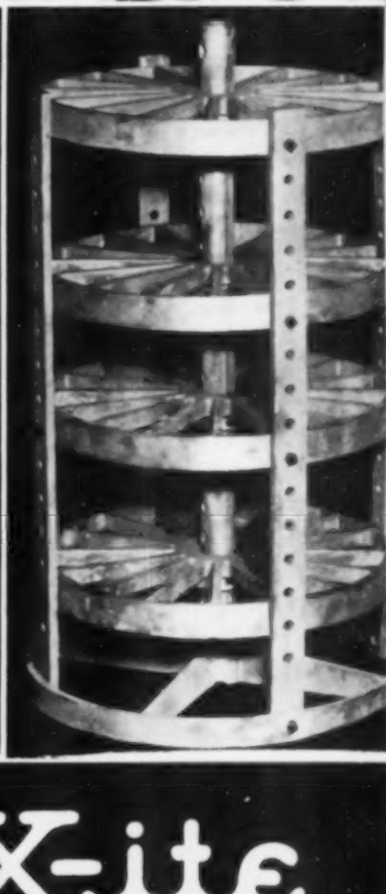
[signature]

**An 8 x 10 photograph of the stone lion and the dog will be sent with our compliments to any member of A. S. M. whose company operates a heat-treat or manufacturers heat-treat equipment.**



***The trick cast heat-treating fixtures on your right are of greater interest, in photographs, or foundry practice, than carburizing boxes, trays or cyanide pots. What will probably interest you far greater is the fact that the largest heat-treats in the world have standardized on Q-Alloy carburizing boxes for years, for the reason that they operate at lowest-cost-per-heat-hour. The proven economies that result in Q-Alloy repeat orders in millions of dollars can be demonstrated in your plant. THERE IS NO SUBSTITUTE FOR EXPERIENCE.***

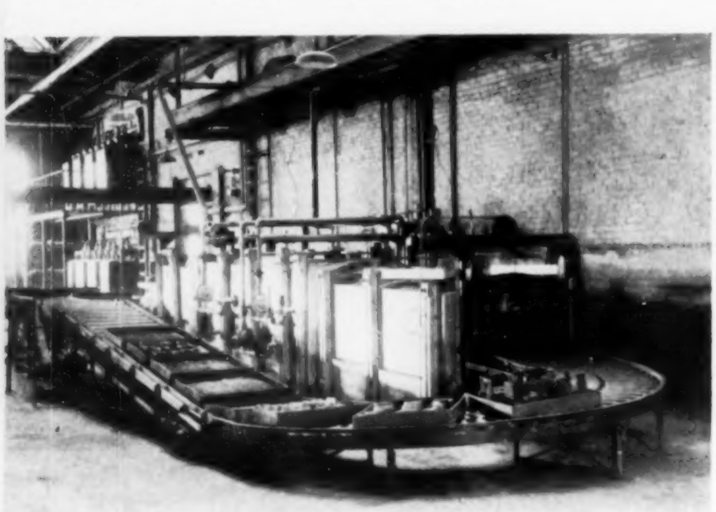




STAINLESS STEEL CASTINGS

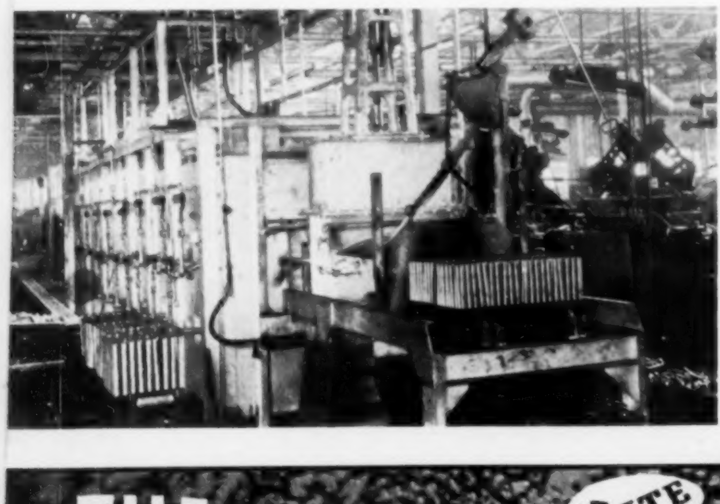

## CORROSION RESISTANT CASTINGS

in a wide variety of analyses are consuming an increasing proportion of our manufacturing capacity. Most users of "Stainless" and the higher Corrosion-resistant alloys have been more-or-less "experimenting with castings." What they really mean is that they have been doing a lot of needless experimenting with sources of supply. You would think that any buyer of alloy castings would include the Oldest and Largest exclusive manufacturer of complex alloy castings when sending out inquiries. Do you?



## SURFACE COMBUSTION FURNACES

just keep bobbing up. You can't keep good furnaces down. I have over eighty cuts on hand of Surface Combustion Furnaces, equipt with General Alloys Cast Mechanical Parts, and fourteen new photographs of more recently installed ones. Soon there will be a lot more, when retorts, combustion tubes, Spiralink chain, rails, and misc. mechanism now being cast in X-ITE is put in service. The furnace above is a SURFACE TRAY ANNEALER, equipt with X-ite trays, roller-rails, etc., and installed in a New England precision tool plant whose name, like General Alloys, stands for QUALITY. The furnace below is a SURFACE GAS CARBURIZER. (Note the load on the X-ite trays).




I WRITE this aboard the M. Y. Guardian in a "Nor'-Easter," rolling in full force from the North Atlantic, at dawn, after a hectic night. Short in main switchboard cut off light and power, which means heat, water-pressure, and galley stove, just dandy in a howling storm with four ¾" steel lines stretching like hemp. Learned that a large bucket of radiator alcohol with steel wool batts "wick" pinch-hits for pressure oil-burner.

MAJOR BING, 155 lb. Great Dane, lies listless in Pneumonia jacket. He was hospitalized in pilot house topsides. Heat interruption cooled in dangerously, so below for Major. Did you ever carry a Great Dane piggy-back down a companionway on a rolling boat? That's one to look forward to.

OSCAR, the Harbour Seal, seeking refuge, is off our Starb'd bow. Peterson, incomparable Steward, viewing Oscar, just remarked "In Norway we boil the fat from Seals' hides, oil our bottoms with it, makes ships sail fast, keep dry, last long." Which makes us wonder how much "progress" modern science really offers. George McCormick would like me to shoot Oscar to sole his skis. Harbour Seal skin on ski runners is glass slippery coasting, with the hair, but climbing, against the hair, a million tiny barbs hold with feathery firmness. But Oscar lives. A storm bound creature gets a break from any Steel Treater.

GLAD I'm not flying in this weather, but some people thrive on it, Charlie Buysse, Circ-Air Furnace Mentor, for instance. Charlie and his gang at Industrial Heating Equipment seek high winds to get three sheets into. When not sailing boats on loose or solid water, they sail skate, a joom-skiddy pastime that puts hair on the chest and ice on the pants. Here's Charles with his skate-sail "Alibi," which does 21 miles on a pint.

IF you like good timely reading, straight hot shots from a rifled pen, write The Chemical Foundation, 654 Madison Ave., N. Y., for their free publications, the "De[...] Village Series" by Francis P. Garv[...] multi-millionaire who has found t[...] give his country superb service, cha[...] ing American Industry and National [...] rity, founding new industries without [...] to himself. Jot this down, now, and [...]

GOT a rather close look at the I[...] State Capitol at Springfield, pho[...] tached, which reminds me of a [...] friend who thus defines a Gentile "[...] who pays retail prices."

FREE beer as a bonus should help [...] Last week the first case arrived. Lo[...] down on a bustling brewery at Ge[...] sympathy flexed my trigger finger. Th[...] the photo might titillate the Brewer. I [...]

it to him, who promptly responded [...] case of comforting beer. Now I am s[...] all breweries, distilleries, and semina[...] sight. If you run a heat-treat in Ke[...] please send us an inquiry for alloy [...]

NOW it's old enough to let [...] humor in Al. Grinnell's boat ex[...] which put Al. and Vi Grinnell in the h[...] for six months. A witness was talk[...] Al. at the hospital:—"BOOO-O-OO[...] blew, just one column of blue flame [...] nert feet up with the boat flyin' lik[...] fetti, an' Al. toppin' it off like a che[...] a Angle Tip." Al., shaking off the [...] anaesthetic, "Was I standing up or [...] down when I was taking off my [...] (The explosive gas filling the space b[...] Al. and his clothes literally blew the [...] off him; he went up as Al., came d[...] Adam.)

THE death of Charles Wesley, Sr., [...] of the Wesley Steel Treating Co. [...] waukee, is a shock and a great loss [...] host of friends. In February he w[...] for operating data on airplanes, p[...] air express service in his busine[...] flying at 71 years. He was plan[...] junket of the Mid-Western Commercia[...] Treaters to the East this summer. [...] Wesley added technology to a l[...] practical experience, attaining distin[...] his field. Proud was he of the abl[...] he left to carry on.

I APPRECIATE being appreciated, [...] for the duck-butter, if you prefe[...] don't we all? My correspondence [...] readers of A.P. is building up, and I [...] it. Joe Doyle, V.-P. of W. S. Rockw[...] writes: "Read your Hirondelle story [...] times." That *is* a compliment!

W. S. Quigley—dynamic "Q" of Hy[...] writes "I want to compliment you—[...] makes interesting reading—would app[...] a few extra copies."

THE FOOTPRINTS OF GENERAL ALLOYS

GA X-ITE  Q-ALLOYS

# HOT HOUSE HONEY

## FROM DISCONTENTED BEES FOR OLD ALLOY PROGRESS CONTRIBUTORS

THE old Alloy Progress, and Alloy arguments had about six hundred contributors. We don't have space for many contributions, but we do want to hear from our old friends. To each of the following men, whose names were drawn from our old A.P. files, who writes in his opinion of A.P., we will send a 5 lb. pail of Hot House Honey. We turn the Bees out to winter pasture on an orchid and gardenia ranch.

A. E. R. Peterka, 2nd, Wm. H. Hunt, W. F. Ginthner, J. J. McCarthy, H. G. Gibson, Edgar Brooker, H. V. Mickle, A. A. Anderson, Herman P. Landrock, George J. O'Neill, O. A. Bamberger, E. F. Larson, E. I. Papworth, K. B. Wilson, J. J. Cushing, C. W. Palmer, Edward H. Erck, Harry Turner, Richard B. Sheridan, James E. Edds, H. C. Ross, John A. Fawcett, Chas. Y. Clayton, F. A. Smith, Jr., Walter Green, Max E. Landry, S. A. Silbermann, John G. Sponsel, George J. Limbert, Otto A. Dworak, Waldo L. Emerson, Thomas A. Connahan, Lawrence H. Seyfar, Myron Park Davis, Stanley T. Dolan, W. D. Latiano, Ralph J. Reed, Edward W. Burd, P. B. Jensen, W. D. Rolfe, F. J. McCarthy, Fred M. Reiter, Philip Kriegel, D. H. W. Felch, R. D. McClaran.


# H. H. DYKE

## AL ALLOYS PATENT COUNSEL

DYKE, of Dyke & Schaines, Patent rneys, New York, will give me Hell sees this in print. It won't be the

the Depression, when some pantyalloy foundry was sitting in every lish Purchasing Agent's lap and his flat beer, I found my Friend sel, Dyke, a good listener, a cool ical thinker, and, in the procureound patents, a go-getter. A sane fundamentalist, looming like an the desert of abandoned hope that York in 1932,—(Do you remember, Y., when the fleas had erected a of dead fleas to the memory of the o,—Dyke is built of and on solid e his home in Larchmont with ved from living rock.

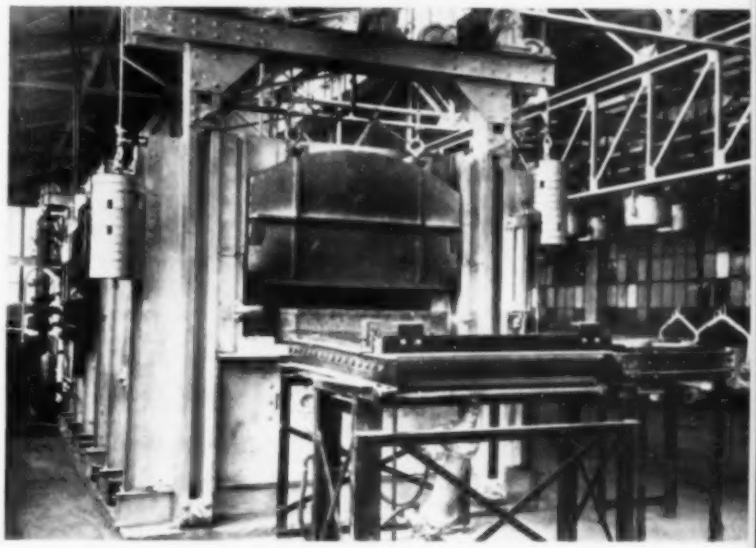
was exposing himself to culture at niversity of Chicago, about the time abdicated, when a friend flunked Office Examiner examination. Dyke xamination, bet he could pass it, climbing aboard the lightly laden at Washington D. C.

his story on landing a job: "All nment clerks in Washington attend l at night and I fell into line. Mr. Edison's head patent attorney used to come to town and stay at a hotel where my boarding-house lady's son worked as a room clerk. The Edison man could not understand how it was that whenever he checked in at night I would be hounding him next morning for a job in the Edison Patent Department, but I wore him down finally and got the job.

"I WAS not in a good trading position, but I had the job, if not much pay, and plenty of incentive to work up. The contact with Mr. Edison was inspirational, and he was wonderfully kind and appreciative of what small services I was able to render toward protecting his inventions and enforcing his patents."

THEN he branched out in private patent law practice and had, "Something to do with a lot of things," such as helping the Ludlum Steel Company get patents on its Silcrome Valve Steel, and maintain them against attacks by U.S. Stainless Steel, and infringement by Crucible Steel; also getting and enforcing the noteworthy patents on Masonite Presdwood, and a score or more other patents for outstanding companies.

H. H. DYKE is another good reason why those distinguished concerns who march forward with General Alloys travel in good company.



# MAHR CARBURIZER

MAHR MFG. CO., of Minneapolis, have built many X-ite equipt furnaces from Texas to Minnesota. The Pusher Carburizer, above, is operating on box carburizing in the plant of a famous name Quality automobile manufacturer in Detroit. This furnace was installed late in 1936, and is giving a splendid account of itself.

X-ite Rollers, set in X-ite rails, carry the boxes through the furnace on trays. This furnace is simple in construction, of a proven type that is suitable for a wide variety of applications.

SVENSEN of Chicago inquires at are those Gadgets on the Kaiser's Prince's beds on the Hirondelle, y be horizontal bundling-bars? t with Nils Nilsen." Wrong, Miss ou should have asked Carl Lindw beds are "Orioles," swinging to ship motion. The "Gadgets" are akfast trays so that the swinging rning tripe be synchronized to the n. Just an acrobatic novelty,— please copy.

WITH a Nor'-Easter blowing, flyers get a good bump out of passing close to the largest drydock in America, at Army Base, Boston, the only U.S. dock where U.S. Lines could dock its Leviathan. It is seldom used for any other purpose. How much more than the ship was worth was paid for the drydock, I do not know. Will U.S. ever build a super liner? Probably not.

MR. L. E. BLAZIER of A. C. Sparkplug knew Hirondelle in Monte Carlo, and writes for her picture. Miss S. R. Jacobs of Industrial Heating Equipment, Detroit, requesting a photo writes "My only regret is that I cannot join in with the boys from six to ninety as I was born a female." We can't hold *that* against her!

JAMES W. GERARD, former U.S. Ambassador to Germany, wrote me, regarding Hirondelle:

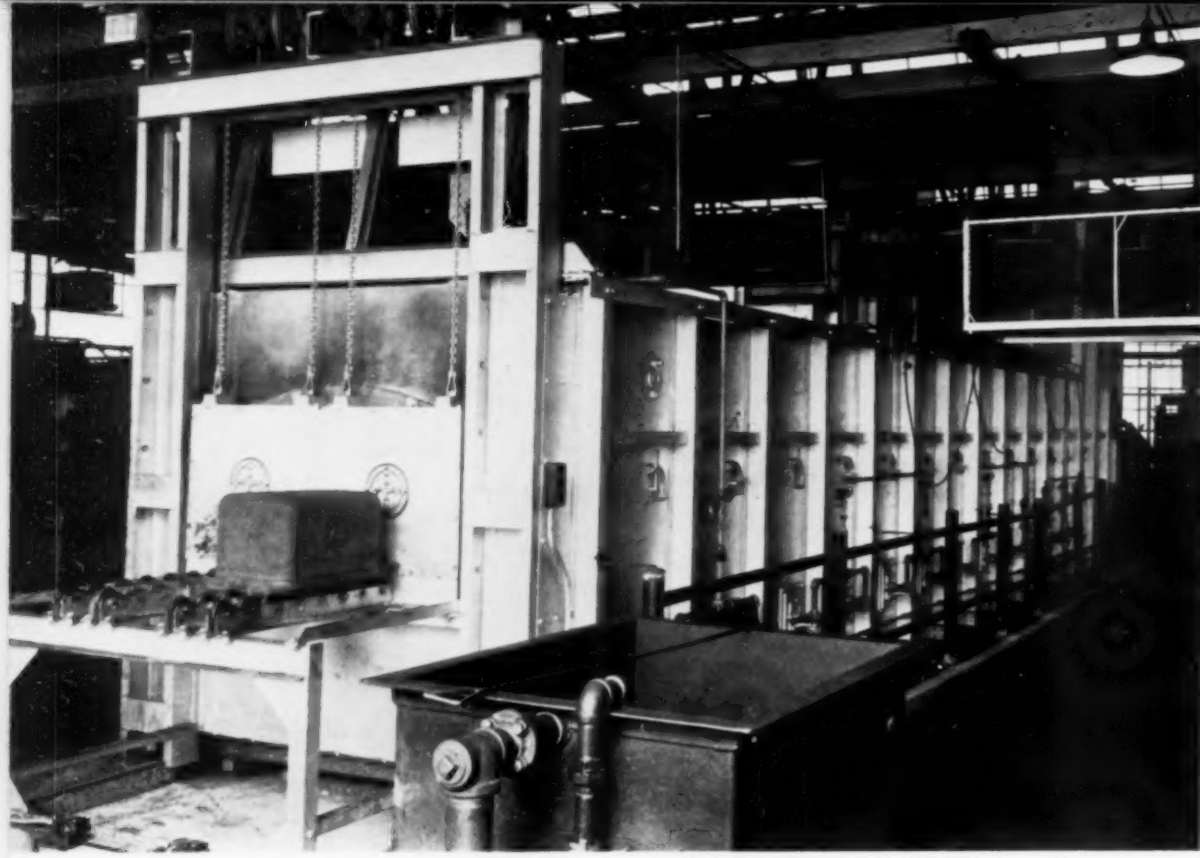
"When I was at Kiel before the war, in June, 1914, the Yacht Utowana on which I was a guest was anchored next to the Prince's yacht. We were rather amused by his flag, which looked like the Twenty of Diamonds, which seemed quite appropriate for a gambling principality.

"The night before we received news of the assassination of the Austrian throne successor at Sarajevo, Mrs. Gerard and I dined on board the yacht with Prince Albert. I think that you will find an account of this in a book which I wrote, called My Four Years in Germany. I am sorry that I do not have a copy at hand to give you the exact quotation.

"When I went abroad to go to Germany in September, 1913, on the Kron Prinzessin Cecilie, the Captain came to me one day and said that the wireless operator on the Prince of Monaco's yacht, which was a long distance away and out of sight, wanted to play for me something which could be heard on our ship's wireless, and I distinctly heard the Merry Widow Waltz. I think that possibly this is almost the first instance of radio transmission."

# YOU PROBABLY USE LEAD OR CYANIDE POTS

IF so you should be familiar with the ROLL-FLANGE Q-ALLOY POTS. This type of pot and separate flange, developed by General Alloys, has many distinct economies and advantages. A few are: Separate flange outlasts from four to a dozen pots. Flange can be made of X-ite, pot of Q-alloy, a material saving. Flange does not restrict expansion of pot as does straight flange. Due to line contact of pot and flange, little heat is lost.

# *Modern* HAGAN FURNACES

## X-ite equipt for
1. Dependable Mechanical Function.
2. Lowest Alloy Cost-per-heat-hour.

THE HAGAN PUSHER CARBURIZER above is a very recent installation in one of the largest and most efficient plants in this country engaged in the manufacture of engine, transmission and axle parts for trucks and tractors, and complete units. We've been chasing Al. Dauch of George J. Hagan Company, Furnace Builders, Pittsburgh, for the operating data and mechanical layout of this furnace. By the time we get it there will be a half dozen more HAGAN furnaces equipt with X-ITE Alloy mechanism in service. This furnace has X-ITE ROLLER RAILS, of course. VETERAN HAGAN FURNACES, equipt with General Alloys alloys, some in service with original Q-Alloy parts 14 YEARS OLD, many with alloy in service eight to twelve years, have built the HAGAN REPUTATION. New X-ITE equipt HAGAN FURNACES will live up to that reputation.

THE FURNACE BELOW, A FOUR-CHAMBER CARBURIZER, WAS INSTALLED IN MARCH 1927.

Operating Data:

Operation — Carburizing — .045 to .070" case.
Type — Regenerative Underfired Pusher Furnace.
Production — Two Boxes per hour, 800 lbs. gross.
Operating Temperature — 1650° F.
Fuel — Gas, 530 BTU at 15 lbs.

Conveyor — Four rows of X-ite Roller Rails.
Pushers — Two twin-screw.
Door Operation — Motorized — Automatic.
Operation of pushers and all doors under control of automatic repeating process instruments.

## SENSIBLE HOR

"HORSE SENSE" is the quality which counsel a man to pay 3c more a p — approx. 5% more, — for X-ite, Nickel, 18% Chrome) than for common 15". This sensible man will get an av of 25% to 40% more service, — if reco the largest alloy users mean any (Horse photo by R. Granger.)

MR. C. H. PARMELEE, Asst. Works ager of the Onondaga Pottery Com has contributed a brief article, on speci applications of hinged trays, based own extensive experience. After readin article, you will no doubt see further bilities in hinged trays. Most of the tray installations to date run under lo approx. 65 to 150 lbs. per sq. ft.

—Ed.

## ALLOY TRAYS FOR LIG LOADS IN LONG FURNA

BY C. H. PARMELEE

HEAT treaters and designers have had placed before them in the tray manufactured by the General Co. an improvement in design to less weight for equal strength with pusher type of furnaces which is peculiarly su to furnaces with heavy concentrat loads for the particular temperature us There is, however, a tray design fabri by this same company which also peculiar application. Designers and treaters having to deal with lengthy fu involving a very light load per square of hearth area but of substantial cros tion, say three foot or more in width one or two feet high, which involv weight concentration per square fo hearth area, twenty-five pounds per s foot or less, may well consider the tion of the forces in their design w between the gravity force of the load in this case is relatively light, and the ing force necessary for pusher tray furnace, which may become large in le furnaces a hundred foot long or longer

A rather novel design for such an ins tion is to separate the tray into a numb members using the lightest members to port the load only and to take none pushing thrust, and using heavier-se members to take the thrust stress. ticular design like this has been very successfully at ..... in a conti pusher tray type of furnace where the ing thrust is taken by a series of tra riers, and on each one of these tray there is loosely interlocked (or hinged light section trays which trays rest tray carriers in their function to support the weight of the goods bein treated. In this case it was possib reduce the weight of alloy involved tray assembly approximately one-ha what good design required in an casting of the same size. Such a would only have an application wh stresses involved in pushing the through the furnace would dictate sections to the tray than would be from the consideration of the weight load alone.

*(Starts on page 416)*

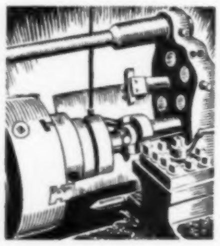
temperatures. Then four pieces (one from each quenching temperature) were tempered for one hour at 930° F., then retempered another hour at 930° F., then retempered for another hour at 930° F. The remaining 20 of the original 24 pieces were split up into five more batches and the same procedure repeated at 970° F., 1005° F., 1040° F., 1075° F., and 1110° F., respectively. This particular experiment was afterwards repeated in toto on another brand of 18:4:1.

Without repeating a great mass of figures, the typical average results from this series of tests are given below.

| Tempering Temperature | One 1-Hr. Period | Two 1-Hr. Periods | Three 1-Hr. Periods |
|---|---|---|---|
| Quenched from 2410° F. to C-64.9 | | | |
| 1005° F. | C-65.5 | C-66.1 | C-66.3 |
| 1040° F. | C-65.8 | C-66.8 | C-66.6 |
| Quenched from 2445° F. to C-64.4 | | | |
| 1005° F. | C-66.0 | C-66.6 | C-66.9 |
| 1040° F. | C-66.3 | C-67.0 | C-66.9 |

During the course of these experiments we satisfied ourselves that two or three tempering periods of one hour each was quite a different thing from one period of two or three hours' duration at any particular temperature.

Further experiments, to see how far this effect of multiple tempering carried on, yielded some interesting and consistent results. Briefly these were that given a quenching temperature of 2390° F. and above, repeated tempering at 1005° F. gradually raised the hardness up to maximum of six temperings of a *total* duration of three hours. After that no further increases were observed after four more temperings of half an hour or one hour each.



When the tempering temperature was raised to 1040° F., however, a very slightly lower maximum was reached, on the average, in the same time and with the same number of repetitions, but any further temperings at this temperature produced a definite and progressive falling off in hardness. Two typical tests

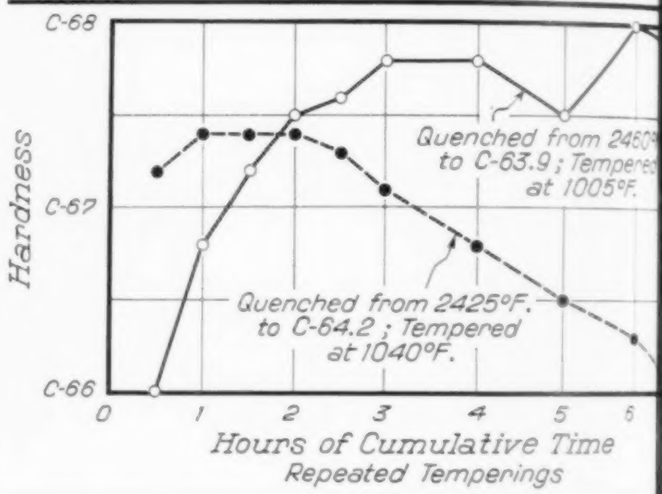
*(Continued on page 448)*

## HIGH SPEED STEEL

*(Starts on page 416)*

in this series (all of which showed similar characteristics) are shown in the graph.

While the Russian letter reported very enthusiastically on the improved cutting ability of steels with such high hardness, induced by repeated tempering, I feel that a note of warning against generalization of these statements may not be untimely. As a result of three years' observations of the results of multiple temper-




*Effect of Repeated Temperings Depends on Quench Temperature and Subsequent Draw Temperature*

ing and very high hardness figures, it would appear that in many cases it is not advisable to bring the standard 18:4:1 or 18:4:2 to such high hardness figures, particularly with many types of form tools such as hobs, circular gear generating cutters or rack cutters. Our experiments and experience on the liability of such cutters to chip have indicated that the brittleness of the sharp cutting edges increases enormously with rise of Rockwell hardness above C-63 or C-64. Where comparatively sharp angled cutting edges have a definite shock blow to meet, we have found it advisable to temper at 1075 to 1100° F. *(beyond* that which gives the maximum hardness) and limit our maximum hardness figure to C-65 or thereabouts. For certain cutters, heavily shock stressed, we even get back to C-62 or C-63.

Francis W. Rowe

# *Help Yourself* *to this* HELPFUL LITERATURE

## Springs Handbook

An excellent presentation is combined with complete technical information in a handsome 88-page book on the art and science of spring making. Illustrations are particularly handsome and well chosen. Published by Barnes-Gibson-Raymond. Bulletin Da-162.

## Copper Bulletin

A new clearing house for news of developments in brass, bronze and copper, the "Copper Alloy Bulletin," issued by the Bridgeport Brass Co., made its appearance with the March issue. It is edited for the technical and engineering audience. Bulletin Da-163.

## Riveting Aluminum

The riveting of aluminum and its alloys is treated from all angles in a comprehensive little booklet by the Aluminum Co. of America. Materials, types, riveting practice for various applications, and properties of the riveted joint are covered. Bulletin Da-54.

## Wheelco Data Book

Complete information on the radio principle, the Limitrol, Flame-otrol, and the complete line of Wheelco pyrometers and accessories is contained in a data book on temperature indicating and control. Bulletin Da-110.

## Tag Controllers

Of interest to many readers will be the new catalog by C. J. Tagliabue Mfg. Co. completely describing and illustrating the latest models of Tag non-indicating controllers for temperature, pressure and time. Bulletin Da-62.

## Pot Furnaces

Pot furnaces for hardening, tempering and forging are described by Surface Combustion Corp. by means of illustrations and complete data concerning an existing installation. The folder also tells about Surface Combustion air heaters. Bulletin Da-51.

## Architectural Stainless

Presented in an unusually attractive format, the United States Steel subsidiaries have recently issued a catalog on stainless steel in architecture, which contains facts, photographs and drawings specially prepared for the architect and his fabricator. Bulletin Da-79.

## Automotive Steels

International Nickel Co.'s bulletin on automotive uses of nickel alloy steels should be of value to all metallurgists and designing engineers in suggesting steel compositions to meet present-day requirements for strength, toughness and dependability. Bulletin Da-45.

## Toolmakers' Microscope

Only recently have optical methods of measuring and testing been introduced in the workshop. These methods — particularly adapted to measuring small and intricate parts — and the equipment used are fully described in a booklet by E. Leitz, Inc. Bulletin Da-47.

## Furnace Parts

A valuable feature of Driver-Harris Co.'s folder on Nichrome cast furnace parts is a table giving the tensile strength of Nichrome castings at various temperatures. Bulletin Da-19.

## Voltmeters

The improved voltmeters and ammeters illustrated, diagrammed and described in Bristol's 23-page catalog embody all of the desirable features developed during 45 years' experience, plus new features to meet the more rigid requirements of today. Bulletin Da-87.

## Mesh Products

Wire mesh is a class of material about which little is heard. A folder by C. O. Jelliff, therefore, telling the special alloys and metals used, styles of weaves and applications is of unique interest. Bulletin Da-78.

## Small Furnaces

American Electric Furnace Co. makes a line of small cylindrical pot furnaces for lead, salt and cyanide that are particularly adapted for the multitude of odd jobs found in manufacturing plants processing metals. Described in Bulletin Da-2.

## Insulation Service

"Barriers to industrial waste" is what Johns-Manville calls insulating materials. A small 64-page booklet catalogs their complete line, which contains a product for every temperature. Bulletin Da-100.

## Grinding Wheels

A valuable and useful book is the new edition of the Norton Company's "Grinding Wheel Specifications for Grinding Machines." List prices are included. Bulletin Da-88.

## Welding Pipe Lines

An improved welding method used in the construction of over 5000 miles of cross-country pipe lines is discussed in a 32-page illustrated booklet published by the The Linde Air Products Co. Bulletin Da-63.

## Fast-Cutting Steel

Bliss & Laughlin, Inc., offer an interesting technical folder on Ultra-Cut Steel, giving performance records of this high-speed screw stock on automatic screw machines. Physical data and microstructures are presented. Bulletin Ob-42.

## Turbo-Compressors

Spencer Turbine Co. has turbo-compressors in all sizes and types for oil and gas-fired furnaces, ovens and foundry cupolas. Special types for special purposes such as gas-tight and corrosion resisting applications are also described in Bulletin Da-70.

## N and Mo in Stainless

A valuable addition to any metallurgist's library is a set of tables giving physical properties of high-nitrogen chromium and chromium-nickel steels and columbium-bearing chromium-nickel steels. Electro Metallurgical Co. Bulletin Da-16.

## Spectrum Analysis

The elements of both qualitative and quantitative spectrum analysis are contained in a handy booklet by Carl Zeiss, Inc. A price list covering all equipment is included. Bulletin Da-28.

## Meehanite

A compact but complete specification chart gives the recommended grades of Meehanite metal for various service requirements. Complete physical properties and applications are included. Bulletin Da-165.

## Heading and Upsetting

A multitude of unusual parts, beautifully photographed and displayed in a folder by Lamson & Sessions Co., can now be produced by heading or upsetting to close tolerances and with an entirely satisfactory finish. The advantages of bolt-making methods are explained. Bulletin Da-164.

## Metals for Corrosion

Fourteen varieties of Midvaloy corrosion and heat resisting metals are described in a detailed bulletin by The Midvale Co. Properties and applications are listed and illustrated. Bulletin Ca-160.

## Oven Furnaces

In a nutshell American Gas Furnace Co.'s improved oven furnaces offer controlled atmosphere, quiet operation, economy, are over and under-fired and bottom vented. Described more fully in Bulletin Aa-11.

## Magnet Steels

A very handsome booklet describes the permanent magnet steels and castings made by Simonds Saw & Steel Co., including Alnico and Alnic. Bulletin Ba-158.

## Copper Welding Rods

American Brass Co. describes in complete detail the welding properties and individual characteristics of 14 different copper alloy welding rods. The 16-page booklet also makes specific recommendations of welding procedure. Bulletin Je-89.

## Tool Steel Selector

A wall chart, 30 x 20 in., to be used as a means for selecting the proper type of tool steel is offered by Carpenter Steel Co. to tool steel users in the U.S.A. only. Bulletin Jz-62.

## Refractory Mortars

How a good refractory mortar properly fulfilling its functions as air-seal, cushion, and bond, will pay for itself in the extended service of furnace brickwork is told in Babcock & Wilcox's bulletin giving properties and recommendations for using various mortars and plastics. Bulletin Ox-75.

## Grain Size Measure

Classification of steels by grain size has become such an important laboratory procedure that Bausch & Lomb Optical Co., at the suggestion of Dr. Marcus A. Grossmann, has developed a grain size measuring eyepiece for microscopes which makes the determination a simple routine matter. Described in Bulletin Ox-35.

## Aerocase

A modern method for case hardening and heat treating steel in a liquid bath is provided by the use of Aerocase compounds, which have been in commercial use for more than six years. Their principal features are described by American Cyanamid and Chemical Corp. in an interesting booklet. Bulletin Oy-148.

## Optical Pyro

No correction charts, accessories nor upkeep are required with the Pyro optical pyrometer, which is a totally self-contained direct-reading precision instrument made by Pyrometer Instrument Co., and described in Bulletin Ay-37.

## Bright Annealing

Illustrated bulletin showing various continuous and batch type electric furnaces for bright annealing, copper brazing, strip annealing, wire annealing, etc., also the Ajax Electric Ammonia Dissociator for producing hydrogen for furnaces using a reducing atmosphere is offered by the Ajax Electric Co. Bulletin Ob-42.

## Hydraulic Tester

Of interest to all engineers recommending or purchasing universal testing machines is a book by Riehle Division of American Machine and Metals, Inc., on the development of the precision hydraulic testing machine. Bulletin Ba-157.

## Globar Elements

Globar electrical heating units and a variety of accessories for their operation have been catalogued by Globar Division of Carborundum Co. Bulletin Oy-25.

# *Some of the Best Thinking*

**in the metal industries is at your disposal in the literature described here. One booklet may hold the key to your current problem. Help yourself to this helpful literature. It's free. You incur no obligation when you return the coupon.**

## New Joining Process

Metal parts are joined cheaply, neatly and strongly by Electric Furnace Co.'s new, inexpensive non-oxidizing furnace atmosphere and their new, continuous brazing, copper and soldering furnaces. Full details are given in Bulletin Ar-30.

## Light Case

Severe breakdown tests were run by A. F. Holden Co. to study the characteristics of Holden Light Case in relation to case penetration and the total change of chemistry of the bath. They are described, and a chart showing results is reproduced, in a folder ready for distribution. Bulletin Dy-55.

## Hardening Furnaces

P. D. M. high speed hardening furnaces are described in two bulletins by The Philadelphia Drying Machine Co. — one devoted to oil-fired and one to gas-fired furnaces, both made in single and twin chamber models. Details of construction, design features and tables of sizes and capacities are included. Bulletin Oy-150.

## Fine Steels

Compiled by men who make fine steels to assist men who use fine steels, a handy, pocket size, 150-page volume by Ludlum Steel Co. contains many new, helpful charts and tables, all made quickly available by a unique method of indexing. Bulletin Aa-94.

## Alloy Castings

Michiana Products Corp. has published a new book describing Michiana corrosion resistant and stainless steel alloys. Generously illustrated, it suggests many savings for the use of these alloys. Bulletin Oy-81.

## X-Ray Examination

The application of X-ray examination and inspection to castings, welding, and food products, as well as practical X-ray crystal analysis, is completely described and strikingly illustrated in General Electric X-Ray Corp.'s new 34-page publication. Bulletin Dy-6.

## Airless Cleaning

Comprehensive coverage of abrasive cleaning and preparation methods by description and illustration is contained in a colorful book published by the American Foundry Equipment Co. It describes the airless abrasive cleaning and preparation method known as "Wheelabrating." Bulletin Dx-112.

## Modern Controls

In view of the present trend toward modernization in industry, Brown Instrument Co. points out the important part played by temperature measurement and control instruments in facilitating operation of efficient equipment for oil refining, steel treatment, chemical, textile, ceramics and other industrial processes. Bulletin Sy-3.

## Molybdenum

Climax Molybdenum Co. presents their annual book giving new developments in molybdenum, particularly as an alloy with iron and steel. The engineering data presented are made clear by many tables and illustrations. Bulletin Dc-4.

## Stainless Data Book

All users of stainless and heat resisting alloys should find invaluable the information contained in a booklet published by Maurath, Inc. giving complete analyses of the alloys produced by the different manufacturers, along with the proper electrodes for welding each of them. Bulletin Jy-125.

## Liquitol

The use of Liquitol for controlled cooling of iron and steel castings and ingots is fully described in a bulletin by Alpha-Lux Co., Inc. Bulletin Ma-120.

## Stress-Strain Recorder

The many applications of the Baldwin-Southwark stress-strain recorder, its unique advantages, and the many ways it can give unusual service will be extremely interesting to all who have to do with testing methods and equipment. Bulletin Ba-67.

## Electrodes

Recommended welding procedures for the new "Shield-Arc 100" electrode as well as all other Lincoln electrodes are contained in the latest "Supplies Bulletin" published by Lincoln Electric Co. Bulletin Ba-10.

## Cleaning Processes

An attractive 12-page booklet entitled "Scientific Metal Cleaning" has been published by Detroit Rex Products Co. It describes in detail the applications and advantages of Detrex degreasing with Perm-A-Clor or Triad Safety Solvents and the applications of Triad Alkali Cleaning Compounds and Strippers. Bulletin Oy-111.

## Stabilog

Ten outstanding advantages of the potentiometer Stabilog are fully explained in an attractively laid-out folder by the Foxboro Co. Bulletin Ba-21.

## Nickel Silver

Riverside Metal Co. has just published a beautiful booklet on nickel silver. If you want the latest information on this subject, presented in an attractive, interesting manner, write for Bulletin Aa-156.

## Sicromo

Timken Steel & Tube Co. has issued a new booklet on Sicromo steels which gives analyses of these new steels and discusses the effect of both silicon and chromium on oxidation resistance. Bulletin Ba-71.

## Laboratory Service

A new edition of "The Metal Analyist" tells about an organization established by Adolph I. Buehler specializing in the installation of metallurgical laboratories. The complete line of laboratory equipment marketed by Buehler is also catalogued. Bulletin Dy-135.

## Nickel-Copper Steels

Exceptional resistance to corrosion and abrasion, increased tensile strength, and higher ductility are the qualities claimed for Youngstown Sheet & Tube Co.'s new series of Yoloy steels. A summary of properties and notes on their characteristics are contained in Bulletin Ox-93.

## Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

## Electric Salt Baths

Literature is available from Bellis Heat Treating Co. describing electrically heated bath furnaces which are economical to operate and have a wide range of applications in hardening, annealing, and heat treatment of high speed steel, stainless steel, nickel, aluminum, copper and bronze, etc. Bulletin Ny-48.

## Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

## Newer Tool Steels

Vulcan Crucible Steel Co. has a complete and attractive catalog listing their full line of tool steels including many special types to meet the modern trends in industry. Bulletin Jy-127.

## Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

## Corrugated Ingots

The Gathmann Engineering Co. has published a new booklet called "Gathmann Ingot Molds — Their Purpose and Design." It illustrates various corrugated ingot contours designed to produce defect-free surface in steel ingots. Bulletin Ay-13.

## Port Valves

Diagrams and descriptive matter show the operation of adjustable port valves made by North American Mfg. Co. that are particularly suitable for mediums whose rate of flow is not constant. Bulletin Oy-138.

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| Da-45 | Da-63 | Ba-158 | Oy-25 | | | | | Ca-68 | Ca-57 |
| | Ob-42 | Je-89 | | | | | | | Ca-8 |

# Helpful Literature

(Continued from page 451)

## Castable Refractory

Properties, method of use, and applications of "Cast-Refract," a time and labor-saving castable refractory made by the Quigley Co., are given in Bulletin Oy-139.

## Photo-Electric Cells

If you are not familiar with the wide field of applications for photo-electric cells and apparatus, send for this very interesting and complete booklet by Pfaltz & Bauer, Inc. covering the original apparatus developed by Dr. Bruno Lange. Bulletin Ca-142.

## Metal Working

Concise but informative is a little booklet by E. F. Houghton & Co. describing various metal-working products — rust preventives, cutting oils, metal cleaners, quenching oils, carburizers, pickling inhibitors, and miscellaneous products. Bulletin Ca-38.

## Cast Vanadium Steel

Jerome Strauss and George L. Norris have written a technical booklet for Vanadium Corp. of America describing the properties developed by steel castings containing various percentages of vanadium. The information given is complete and authoritative. Bulletin S-27.

## Micromax Model

A novel publication by Leeds & Northrup Co. has the effect of almost putting a half-size model of the Silver Anniversary Micromax recorder in your hands. Cut to the actual shape of the recorder, it can be opened out and the whole mechanism swung into place. Bulletin Ca-46.

## Resistance Wire

A complete catalog of the various types of electric resistance wires made by Hoskins Mfg. Co. has been issued. Complete numerical data are included on all types, along with some fundamental facts about heating units. A handy, small size 48-page booklet. Bulletin Jy-24.

## Centrifugal Castings

Centrifugal casting of stainless, heat and corrosion resisting alloys eliminates impurities and cooling strains and permits thinner and more uniform walls than any other method. This is explained in a bulletin by Michigan Steel Casting Co. Bulletin Nx-84.

## Cleaning Rooms

A catalog of designs for blast cleaning rooms incorporating many labor and time saving improvements making the blast room an unequalled mechanical device for low cost cleaning is published by Pangborn Corporation. Bulletin Ca-69.

## Thermit Welding

Of interest to all who are concerned with welding, but of particular interest to students is a pamphlet of carefully explained and illustrated laboratory experiments in Thermit welding published by Metal & Thermit Corp. Bulletin Ca-64.

## Ni-Cr Castings

Compositions, properties, and uses of the high nickel-chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

## Die Blocks

A handy, small size spiral-bound leather notebook is a complete handbook on Heppenstall Company's die blocks. Valuable additional data are contained, as well as a few blank pages for memoranda. Bulletin Ca-122.

## Gas-Fired Cyclone

Lindberg Steel Treating Co. has announced a gas-fired Cyclone furnace as a companion to the electric Cyclone. Complete data in the form of diagrams, charts, photographs, and blueprints are found in a new catalog. Bulletin Jy-66.

## Brinell Tester

Accurate and exact measurements can be made on hard or soft materials with the Diamo-Brinell hardness testing machine, which uses a pyramid-shaped diamond instead of a steel ball. Described in a pamphlet by Pittsburgh Instrument and Machine Co. Bulletin Aa-1.

## Grinding Lubrication

A handy outline for the selection of grinding wheels is one of the useful features of a booklet full of facts about grinding solutions. D. A. Stuart & Co. Bulletin My-118.

## Rockwell Tester

A revised and completely up-to-date catalog on the well-known Rockwell hardness tester is well illustrated and contains 24 pages. Published by Wilson Mechanical Instrument Co., Inc. Bulletin Ca-22.

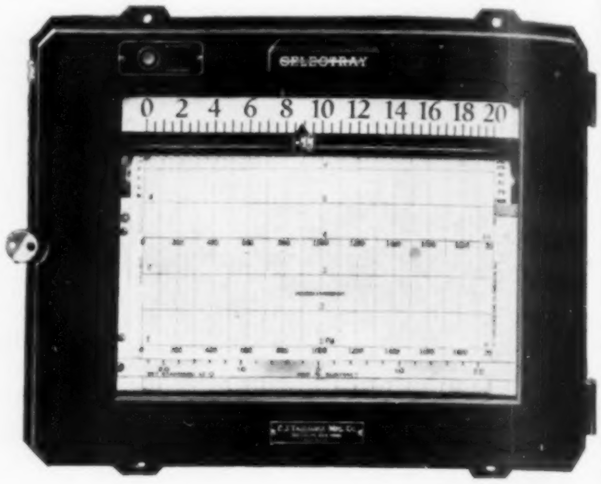
## Diamond Wheels

A striking presentation is made by the Carborundum Co. in a 52-page booklet on diamond wheels. Detailed technical information is contained and a price list attached. Bulletin Ca-57.

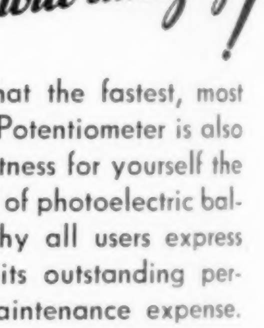
## 4 to 6% Cr

Fifth of the series of beautifully printed booklets describing Republic Steel Corp.'s Enduro types is concerned with the 4 to 6% chromium steel. Its particular application to oil refining is described in detail. Bulletin Ca-8.

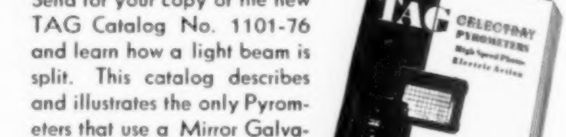








METAL PROGRESS

*Vol. 31* *May, 1937* *No. 5*

# The Rise of High Purity Zinc

*An Editorial*

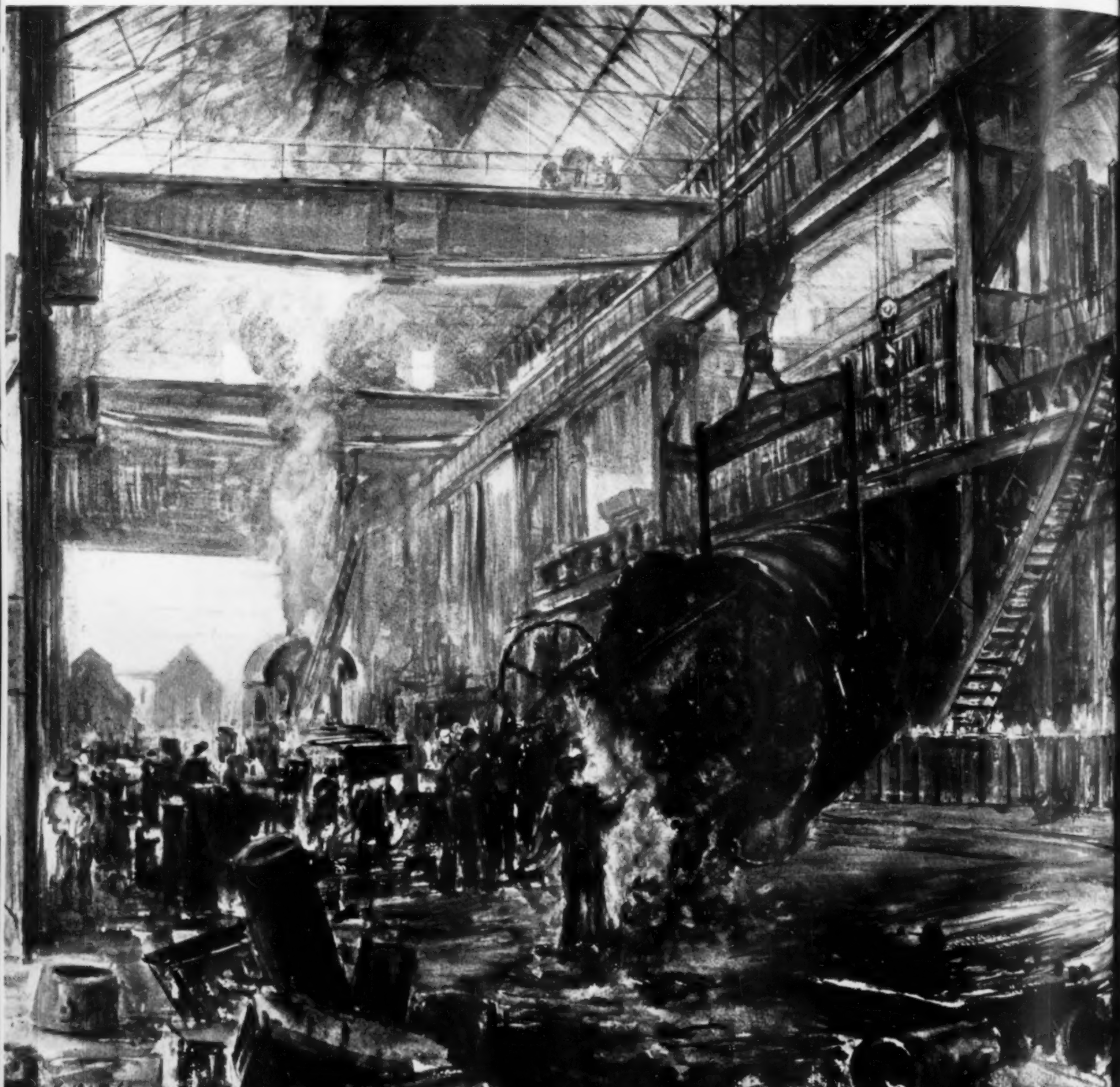
Interesting and significant changes have taken place in zinc smelting in the last 25 years, upsetting methods entrenched for two centuries — and the end is not yet reached. Using the term "zinc smelting" loosely enough to include the electrolytic process, successfully commercialized just before the War, we find that the latter is now responsible for well over a third of the world's production and this proportion grows annually.

Distillation processes retain a larger share in America, due to the important deposits of unusually pure ores in northern New Jersey and the fortunate proximity of rich ore and cheap natural gas in Southern Missouri. Improvements in the traditional distillation process may even halt the trend in the United States, for metallurgists of the New Jersey Zinc Co. have developed, in the last decade, mechanized furnaces capable of producing five tons of liquid zinc per day in each vertical retort, and this metal is convertible to 99.99% purity by a single "rectification" redistillation. Likewise St. Joseph Lead Co.'s men are operating a good sized plant wherein first quality zinc oxide (and zinc on occasion) is produced electrothermically in shaft furnaces 6 ft. in diameter and 37 ft. high, a long jump ahead of the old retort.

In this field of metals, however, the rise of electrolytic zinc is the most notable post-War trend. The Editor well remembers the tiresome number of lectures by his professor of metallurgy on "the complex ore problem": Gold and silver ores with lead, copper and zinc minerals so inextricably mixed that they could not be separated by gravity concentration, and only with the greatest of difficulty and with criminal wastage could the concentrates be smelted for the precious metals. Flotation and differential flotation came later to improve the mechanical separations during concentration, but the problem of a low-grade zinc ore or concentrate (still too poor for distillation) remained.

Here was the opportunity for the electrolytic process. It was successfully achieved in three places at about the same time and using substantially the same methods at Broken Hill in Australia, Trail in British Columbia, and Anaconda and Great Falls in Montana. In each locality the process surmounted some limitation of the older method, such as low grade or impure ore, lack of suitable fuel or auxiliary raw material, lack of ample man power. *Purity* was a byproduct of utmost importance — *pure zinc*, that is zinc with less than 0.01% total impurities. It came that way because you get little deposit unless the zinc sulphate solutions are purified to a wholly unprecedented degree. (Zinc of this high purity was also obtained at about the same time by a distillation method.) This pure zinc, in turn, was lucky for the die casters, who found that 99.99% zinc is essential for their alloys, else they swell or even crumble in moist warm climates. But from the electrolytic zinc producer's standpoint, this is merely a desirable incidental.

So we find today that pure zinc has the upper hand. When the electrolytic plants outgrew their infantile diseases (and they were many and serious) it was found that the over-all cost of this fine zinc was competitive with the relatively impure spelter, distilled in retorts. This condition is world wide, for a recent tabulation shows 24 plants in 12 countries ranging from Siberia to Rhodesia and Australia to Norway, and, as noted at the outset, more than one third the zinc made in 1937 will come from this extraordinary development of the electrical age.



*A Reminder of a Great War*

*Sir Robert Hadfield, Honorary Member, sends this photograph of a painting by Herbert J. Finn made in 1918 in one of his openhearth shops which during that year and the preceding made a quarter of a million tons of ingots for high explosive shells, gas shells and armor piercing projectiles*

*Galvanizing of sheet iron by dipping in molten zinc is a century-old process, and is now the most extensively used method of surface protection. A modern method for improving the properties of the coating is the heat treatment termed "galvannealing"*

# Galvanized Sheets and Galvannealed Sheets

A GALVANIZED SHEET is a zinc-coated iron or steel sheet, the name galvanizing having been applied to the process in the early part of the 19th century by Sir Humphrey Davy. All zinc coatings are called "galvanized" regardless of the base material and the process by which the coating has been applied. There are at least eight known processes by which zinc may be applied to steel, but the so-called "hot-dip galvanizing process" is the only one that has come into general use.

The term "galvannealed" is coined to apply to a zinc coating which has been subjected to a heat treatment before solidification. Regular, or ordinary, galvanized sheet surfaces are spangled. Galvannealed sheets have a matte surface, free from spangles. The two are contrasted by the cover of this issue of METAL PROGRESS and the macrograph on page 502.

Zinc coatings may be applied to steel by a continuous process such as is used for wire, by hand-dipping as used for certain hardware products, by batch coating as used for nails, bolts and the like, and by the intermittent or semi-continuous process used for coating sheets. Originally sheets were coated by a hand-dipping process, which was described about 100 years ago as follows:

"I will notice in this place that the article which will probably be considered of the most importance is Sheet Iron destined either for the sheathing of vessels, — or for roofing of every kind. — this naturally leads me to describe the best method of preparing these sheets of Iron, so they may not be rendered brittle and unfit for use: after cleansing the oxyde of the surface of the sheets of Iron by means of acids diluted with water, we arrive at the extremely important point of dipping the sheets of Iron in the melted zinc: the true art of galvanizing these sheets of Iron, being thoroughly cleansed previously from the oxyde, is to have the zinc bath as hot as possible and well covered with the muriatic salt, and as the salt consumes as much more rapidly, as the zinc is more intensely heated, it is necessary to have a pail of salt close at hand, so that the workman may be able to throw on the surface of the zinc fresh salt as often as he perceives it is required. Let there be no stint of salt if you wish to do the articles well. The workman dips the sheet of iron, which he holds by pincers, into the zinced bath, quick, briskly, leaves it in for a quarter of a minute or so, balances the sheet in the prongs of the pincers, which he moves to prevent any trace of the pincers being left on the Sheet of Iron, then draws out the sheet slowly and hands it over to another workman who is placed on the opposite side of the bath to him. This second workman will take the Sheet of Iron after being very particular to dip the edge of the sheet into the flux — he will carry it and stand it on its edge on a

**By J. L. Schueler**
**Superintendent, Steel and Wire Division**
**Continental Steel Corp.,**
**Kokomo, Indiana**

wooden frame made on purpose to contain them. Here my worthy readers will please to remark, the Sheet of Iron has not yet touched the water, either warm or cold; and I particularly recommend to all those who wish to have good malleable Sheets of Iron not to be too hasty in plunging the sheets into water. It is better for the toughness and malleability of the Iron to leave it become cooler (say from 5 to 10 minutes) than when it quits the zinc bath, before attempting to wash off the blackish stains caused by the muriatic salt. . . . When zincing several sheets at a time (six for instance) they place them on a grating that they hold with two handles. The sheets ought not to touch one another. They hinder their contact by iron wires turned back and fixed on the grating by the two extremities, and placed between each sheet."

## Modern Galvanizing Process

Improvements in equipment for handling sheets, temperature control for pickling and galvanizing baths, and many other factors have changed this old hand-dipping method considerably, although the fundamentals of the coating process remain the same.

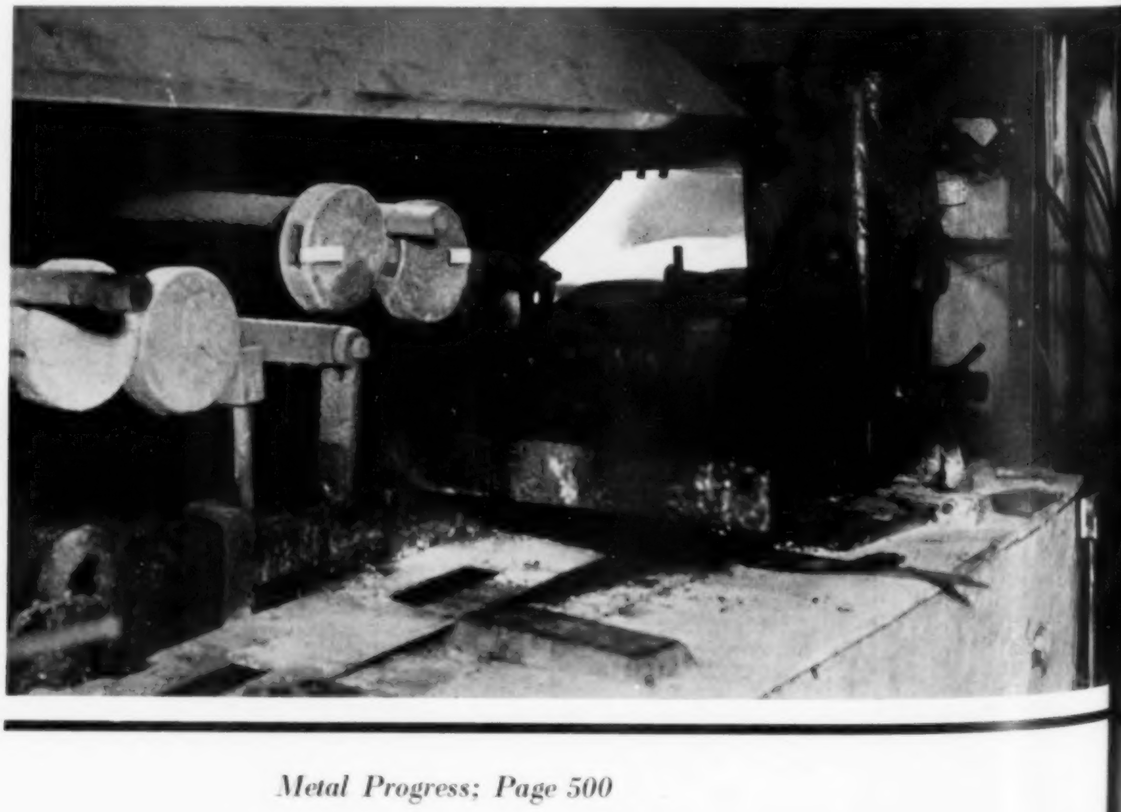
Before an adherent zinc coating can be applied, it is necessary that the steel surface be chemically clean. Therefore, the surfaces of the annealed sheets received from the rolling mill are cleaned by immersing them in acid — usually a sulphuric acid solution having a strength of about 7.5% and maintained at about 160° F. The sheets are carried loosely in crates and are constantly agitated during the operation. The cleaned sheets are removed from the acid and thoroughly washed in water or in a sodium carbonate solution to remove the acid. They are then kept under water for a sufficient length of time to remove any absorbed hydrogen and to prevent rusting.

Prior to coating, the sheets are immersed in a water bath slightly acidulated with muriatic acid. From this solution driven rubber rollers enter the sheets, singly, into a sal ammoniac (ammonium chloride) flux, contained in a box floating on top of the molten zinc.

Sheets are then passed mechanically through the molten zinc and up out of the bath through driven exit rolls. These exit rolls are grooved so that the metal will be distributed as evenly as possible over the entire surface of each sheet. The gage of the sheet, the level of the molten metal in relation to the rolls, the size of the grooving in the rolls, the speed at which the sheet travels, and the bath temperature, all have a bearing on the weight of coating remaining on the sheet. This is ordinarily expressed as ounces per sq.ft.; 1¼ oz. per sq.ft. being a fairly heavy coating, as galvanized sheets are produced today.

For example, if the coating is to be heavy, then the temperature of the bath is raised, the

*"Spelter Pot" (at Left) Discharges Galvanized Sheet Into Heat Treating Furnace*



molten zinc increased so that its level lies high in the pinch of the rolls, and the width and depth of the grooves in the exit rolls are increased over that for lighter coatings.

### Preparing Light Coatings

Sometimes, when very light coatings are desired, as in class 5, described later, the zinc is floated on a bath of lead, so that the sheet in its travel through the pot does not come in contact with the coating metal until just prior to entering the exit rolls. The foreign "Aplataer process" appears to be a modification of this. Still another process is carried out by blowing powdered sal ammoniac across the sheet at the exit rolls. Except in the last mentioned method, the coated sheet after leaving the galvanizing bath is not forcibly cooled or washed, being allowed to cool slowly in air. This is ordinarily done in a slowly revolving spider wheel, having a multitude of radial rods forming skeleton shelves for supporting the sheets singly.

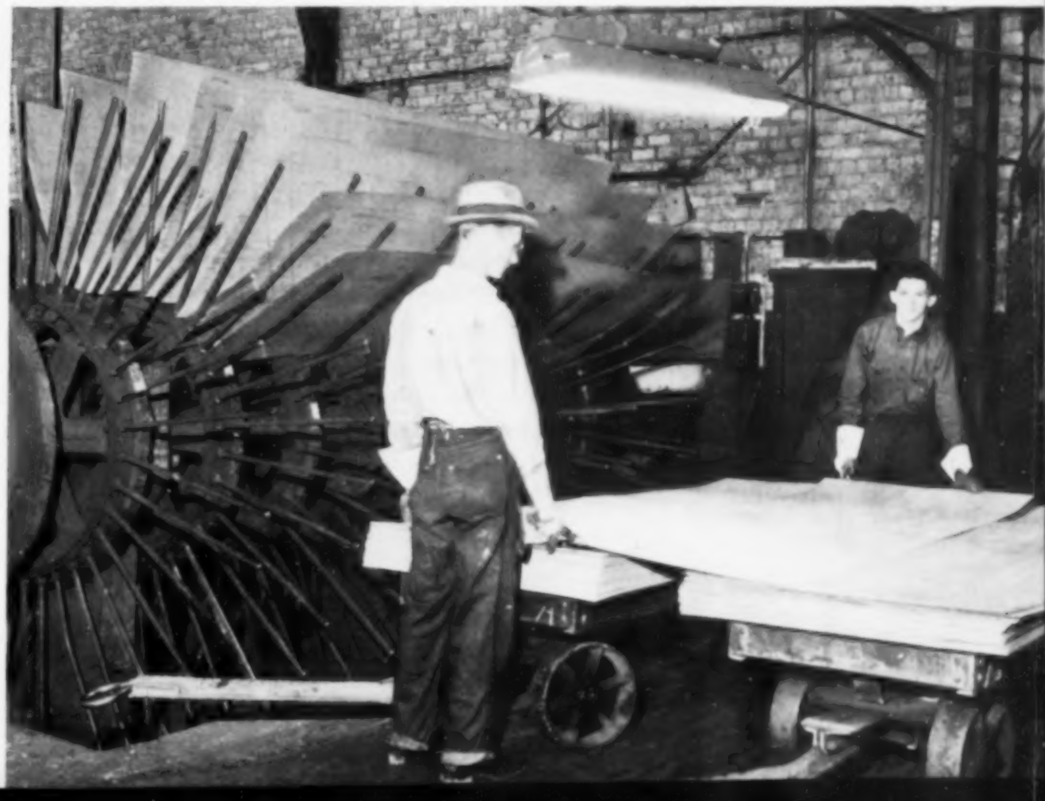
Slow cooling of the metallic coating causes the formation of large bright spangles; the zinc crystallizing in frost patterns. Size and brightness of the spangles may be further controlled by the use of small amounts of tin or antimony in the bath. The size and regularity of the spangle may also be controlled by mechanical means. The spangled galvanized surface has a slick, greasy feel, although actually there is no grease present.

The sheet galvannealing process is identical with the sheet galvanizing process up to the point where the sheet leaves the zinc pot. Then, instead of being allowed to cool, as in the galvanizing process, the coated sheet is passed into a heat treating (galvannealing) furnace where the coating is subjected to a temperature of about 1200° F. (650° C.) or higher, depending on the gage of the sheet, the weight of the coating, the speed of sheet travel and the length of the galvannealing furnace. After heat treatment the galvannealed sheets are cooled in air in the conventional manner and equipment.

The temperature of this heat treatment, or galvannealing, is well above the melting point of pure zinc (787° F.) and is in the region where the iron-zinc compounds are stable. This prevents the formation of spangles on the sheet and produces a silver-grey matte surface. It also causes the coating, if normally heavy and brittle, to become more malleable and, to some extent, causes a redistribution of the zinc to form a coating more uniform in structure. The accompanying micro on page 502 may be compared with those of hot-dip galvanized coatings shown in the data sheet in METAL PROGRESS for September 1935.

The purpose of any zinc coating is to cover the steel with a highly impervious metal which

*"Galvannealed" Sheets Are Hot-Dipped in Conventional Equipment, But the Hot Sheets Are Immediately Conveyed Through a Heat-Treating Furnace, Held Considerably Above the Melting Point of Zinc. Through an open door the front end of the sheet can be seen as it enters a cooling tunnel, from which it is placed on the porcupine cooling rack for final inspection*



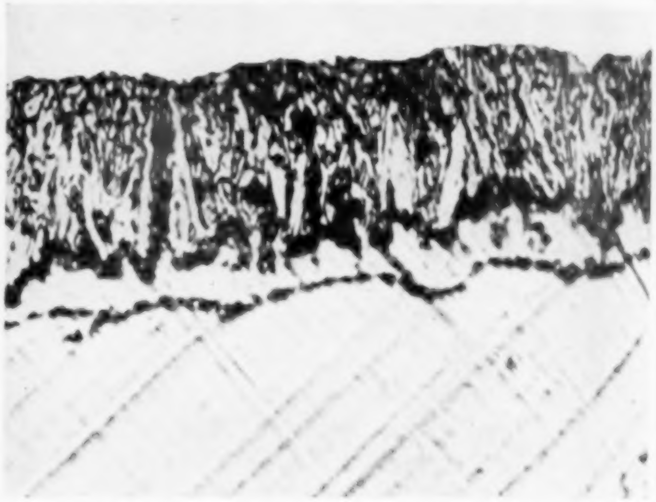
in itself is sufficiently resistant to corrosion to have a reasonably long life. Other things being equal, a heavy or thick coating of zinc will take longer to be consumed by corrosion than will a light or thinner coating. Heavy zinc coatings, however, are inherently brittle. For this reason, it is necessary to produce a variety of galvanized sheets differing from each other principally in the amount of coating metal carried per unit of sheet area. These may be grouped as follows:

1. Heavily coated material intended for roofing, siding and flat work where no forming more severe than corrugating is intended.
2. Similar to group 1, but not so heavily coated, intended for general sheet metal work requiring not more than moderate bending.
3. An intermediate coating which will stand more forming than the two preceding groups, but which will not stand severe forming.
4. An extra-tight coated material which will stand fairly severe forming, and still carry a moderate weight of coating.
5. Special coated material used for the most severe forming and carrying only a very light weight of zinc.

Besides the forming and fabricating requirements, it is also frequently necessary that the galvanized surface be painted, enameled, lacquered, or varnished. We know from ample experience that these non-metallic coatings will not adhere to a new spangled zinc surface; consequently it becomes necessary to etch these surfaces either chemically or mechanically before application of paints and the like.

Chemicals used for this purpose are displacement agents such as copper or antimony salt solutions; acids, such as dilute hydrochloric, or acetic; and aging or weathering of the coating (probably a combination of chemical and mechanical etching). Mechanical methods used are light blasting with sand or other suitable gritty material, or scouring with the aid

*Appearance of Matte Surface of Galvannealed Sheet When Magnified 25 Times. This naturally gives an excellent "tooth" for paint and lacquer*



*Heat Treatment After Galvanizing Causes Practically Uniform Diffusion of Iron-Zinc Compounds Throughout Coating. Magnified 900 dia.*

of abrasives. The object of these treatments is to produce an etched zinc surface which will act as a key or bond for the paint. Regardless of whether a chemical or mechanical process is used for etching, some of the galvanized coating is removed. In some cases, where chemical methods are used, a corrosive residue may be left on the surface, which, unless very carefully removed, will later cause the paint to peel.

### Advantages of Galvannealed Surface

The galvannealed surface differs radically from the galvanized surface in that it requires no etching treatment of any kind prior to painting or enameling. The galvannealed matte surface, being inherently of the "etched" type, holds these materials directly. The only surface preparation necessary is the removal of moisture, oil, grease or foreign material.

Furthermore, the zinc-iron alloy formed in the coating during the heat treatment so bonds

the coating to the steel, that the galvannealed coating will withstand severe deformation without becoming detached from the steel base. The zinc-iron alloy also has a high resistance to atmospheric corrosion so that galvannealed sheets have become standard material for road signs, road markers, license plates, billboard sheets, cabinets, air conditioning equipment, bus and automobile parts, exterior and interior metal trim, sash and frames, and many other uses requiring severe forming, resistance to atmospheric corrosion, and ease of application of paints, enamels, lacquers, and varnishes and other decorative finishes.

# Alloying Zinc Baths for Galvanizing

**By G. A. Brayton**

*Abstract from paper for American Zinc Institute, 1936 Meeting*

In galvanizing steel sheet, uniformity, appearance and adherence of the coating are of importance. The composition of the zinc bath affects all of the above features and also the workability of the bath.

Metals commonly used for alloys are tin, antimony and aluminum; in addition there are always present lead and iron. If we purchase the purest zinc made, it would, as soon as it melted, begin to alloy with the iron of the steel pot, and to a much greater extent with the iron of the product being coated. The chemical reaction of the zinc with the iron chloride carried on the sheet from the cleaning box into the bath also produces zinc-iron alloy (dross) and zinc chloride. Part of the dross settles gradually to the bottom of the pot and part, in the case of sheet galvanizing, is carried out on the sheet, forming the inner layer of the coating.

There is also 0.50 to 1.00% lead in the zinc, according to the grade of spelter purchased. The amount alloyed with the zinc depends upon the temperature of the bath. As the pot cools, the unalloyed lead sinks to the bottom of the pot beneath the dross where it is more or less trapped until the bath is stirred up in drossing.

Both lead and iron must be considered as undesirable impurities, but under present commercial conditions, impossible of elimination.

The appearance of sheets coated without other zinc alloys than iron and lead is smeary and not uniform unless fluxed. It carries some small white arrow-shaped spangles in a field of blue, is unattractive to the trade and discolors easily. The general custom has been to add tin to produce more white spangles and improve the appearance. Like iron and lead, tin is more easily corroded than zinc and in some specifications it is considered an impurity and limited in amount. It increases workability of the bath and uniformity and adherence of the coating; in these respects it improves the resistance to corrosion. One and one-half per cent tin in the coating produces irregularly pointed spangles, mostly white and feathery. All other things being equal, it increases the size of the spangles. Sheets of this sort tarnish slowly. Greater amounts improve the adherence of the coating to a marked extent; however, the amount must be kept low because of the relatively high cost —about ten times that of zinc.

Antimony alloys with zinc in all proportions. It decreases the size of the spangles very materially but when used with tin it adds luster to the spangle and increases the amount of blue spangles, especially when fluxed. It decreases adherence of the coating on the sheets and does not improve the workability of the bath.

Antimony, tin and cadmium used in dip pots produce very attractive, large and sharply delineated spangles.

Aluminum has no place in a sheet pot except, perhaps, over the week-end to physic the metal. It diffuses through the metal with great rapidity and its power to bring the dirt up causes black spots on the sheets. In dip pots for small pieces with small surface relative to the mass, and where pieces are turned over in process, it produces a beautiful product with few white spangles on bright blue metal which holds its luster for a long time. This coating is adherent and fairly uniform.

It should not be forgotten, of course, that mechanical improvements in the sheet mill, the rolling, annealing and pickling of sheet, have been responsible for considerable improvement in the appearance and adhesion of the galvanized surface.

*Everyone who has done much carburizing has been worried by unexpected differences in the time required to produce a case of standard depth. This article shows how composition of the steel affects the carbide diffusion*

# Diffusion Through Ferrous Welds of Duo Clad Metals

THE LETTER from A. V. Prohoroff in the February issue of METAL PROGRESS is of great interest to the present writer, who has on numerous occasions observed marked ferrite banding due to alloying elements segregated under unusual circumstances. Whereas Prohoroff produces his banding by diffusion of elements between high carbon steel and alloy steels, the writer produces it by diffusion of elements from alloy steels into pure iron, and believes that some of his observations, recorded as photomicrographs, may be of interest.

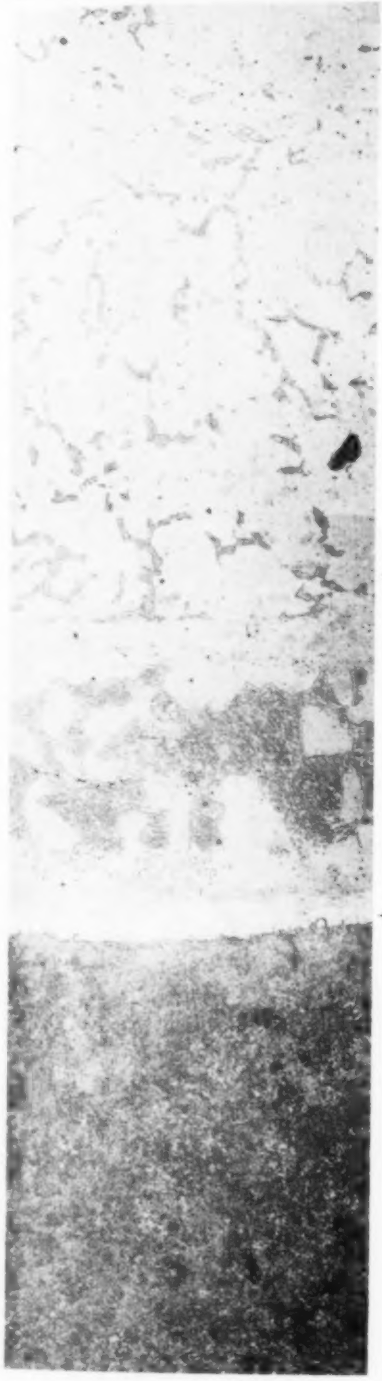
These observations were made upon samples of clad ferrous metals produced by the Armstrong process at the plant of Latrobe Electric Steel Co., which has been fully described elsewhere by R. R. Rogers ("Cladding of Ferrous Products," *Industrial & Engineering Chemistry*, 1935, Vol. 27, p. 783) and the present writer ("New Method for Welding Together Ferrous Metals by Application of Heat and Pressure," *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 120, p. 363). Briefly, it consists of depositing 0.006 to 0.012 in. of electrolytic iron upon the surfaces of the two metals it is desired to weld, placing these surfaces in contact, protecting them from oxidation during heating, and then rolling or forging so that a weld is made. Diffusion readily takes place across the thin layer of pure iron during any subsequent heat treatment.

It is essential that the surfaces should be chemically clean, and this is effected as follows: Scale will be removed during electrolytic pickling (or by sandblasting the more difficultly soluble alloys). All grease is removed by making the metal cathodic, for a few minutes, at a low density in hot, dilute sodium hydrate. Final pickling is done in 8N hydrochloric acid; the metal is made the anode for 15 min.; current density is about 100 amp. per sq.ft. After washing and scrubbing free from sludge, the metal is dipped briefly in the acid solution and immediately transferred, wet, to the plating bath.

The iron plating bath used is a Fisher-Langbein solution (4N ferrous chloride, 6N calcium chloride, and 0.01N free hydrochloric acid) operated at a temperature higher than 180° F., the solution being circulated and completely filtered during every 20 min. The work is made cathodic, and plated at a current density of 100 amp. per sq.ft. or more. One hour gives a deposit of iron 0.006 in. thick, which is sufficient for most alloy steels. The resulting plate is soft, ductile, and smooth, and will not chip or spall off.

The dried pieces that go to make up a composite billet are then assembled in a powerful vise, and a continuous bead of weld metal run

**By Leonard C. Grimshaw**
Superintendent, Duo Metals Division
Latrobe Electric Steel Co.
Latrobe, Pa.

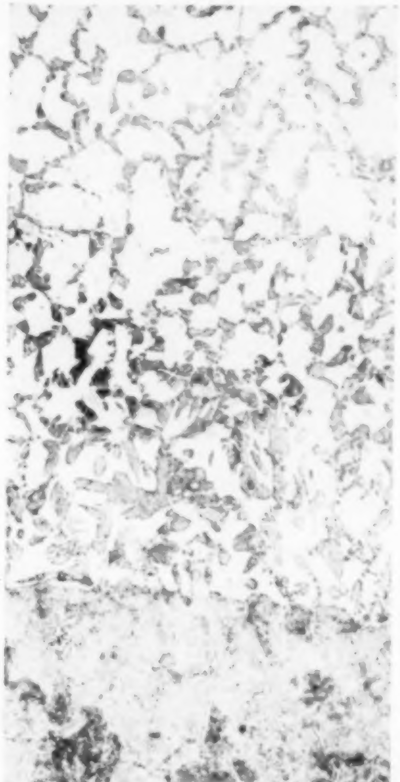


C 0.10%
Si 0.47%
Mn 0.36%

Arrows mark outer limits of original electrolytic iron; center of weld identified by oxide inclusions

C 0.98%
Si 0.31%
Mn 1.63%

*Annealed at 1450° F.*



*Annealed at 1450° F. and Oil Quenched From 1450° F.*

***Diffusion of Carbon From a Manganese Steel to a Soft Steel***

around the joint. This holds the billet together during heating and prevents the electrolytic iron from oxidation. If one of the metals is air hardening and therefore of a nature that it might crack if welded at the edge with an electric arc, double, or two-high assemblies may be arranged and a $\frac{3}{16}$-in. plate wide enough to cover the sides is welded along each edge to the softer backing. The abutting surfaces to be welded are then contained in a tightly fitting metal box. These side and end straps are easily split off after the composite billet has been rolled sufficiently to make a good weld.

The photomicrographs shown herewith were purposely taken of weld zones that contained a few oxides between the original surfaces of electrolytic iron, although such oxides are rare in welds produced by the Armstrong process, as the above is known. Thus we can always determine the middle of the original zone of electrolytic iron, no matter how masked it may be by diffusion. Care was taken that the steel surfaces were free of decarburization before the electrolytic iron was deposited. All samples were etched in 2% nital, and photographed at 160 diameters.

The first pair on this page show a steel containing 0.98% carbon and 1.63% manganese welded to a 0.10% carbon steel that has been given a long commercial anneal at 1450° F. The weld zone is 0.011 to 0.012 in. wide, and although it was once pure iron, we now see in the annealed sample (left micro) the same structure of pearlite with a band of ferrite on each side of it that Prohoroff shows in his weld zone after carbon diffusion has taken place in the presence of manganese. Notice also that the 0.10% carbon steel has picked up carbon that has migrated across the weld zone from the manganese steel.

The latter fact is more clearly shown in the right micrograph above, which shows the same sample after holding a few minutes at 1450° F. and oil quenching. The diffusion of carbon at 1450° F. that takes place during the few minutes the piece was reheated prior to quenching is of negligible amount, and yet we see after the oil quench that there is high carbon dis-

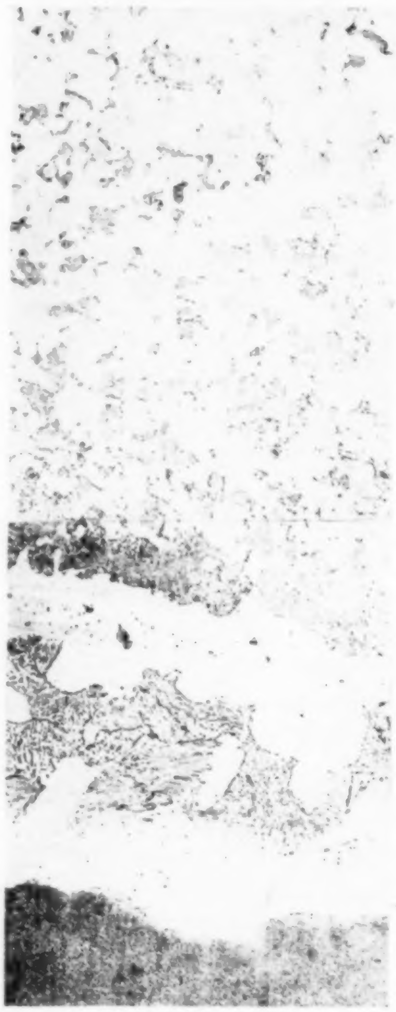
tributed in a graduated but uniform manner all across the weld zone, with no trace of ferrite bands. The 0.10% carbon steel is now clearly seen to have picked up considerable carbon for a distance of at least 0.012 in. during the anneal.

By this method of welding, we can go a little further than Prohoroff, and examine the diffusion of carbon from high speed steels, or high carbon, high chromium steels, which possess more stable carbides. The second group on this page shows the weld between 18-4-1 high speed steel and 0.10% carbon steel after a commercial anneal at 1680° F., and the same weld after oil quenching from 2350° F. The ferrite bands disappear after the quench. The quenched sample shows beautifully the fact that very little carbon gets free from the high speed steel at 1680° F.; appreciable amounts go only 0.009 or 0.010 in. across the weld zone.

Notice also in the right hand micro in this pair, that if it were not for the fact that oxides were intentionally included to show us the center of the weld zone on lighter etching, we would be completely misled as to its width. However, we also see that some carbon freed itself from the high speed steel near the beginning of the long anneal, and that this small amount migrated a total distance of about 0.034 in. from the high speed steel — further than it did from the manganese steel shown on page 505, due to the higher annealing temperature.

*Very Little Carbon Is Able to Diffuse From High Speed Steel at 1680° F.*

C 0.10%
Si 0.47%
Mn 0.36%



*Annealed at 1680° F.*

Arrows mark outer limits of original electrolytic iron; center of weld identified by oxide inclusions

C 0.68%
Cr 3.96%
W 17.53%
V 1.05%

*Annealed at 1680° F. and Oil Quenched From 2350° F.*

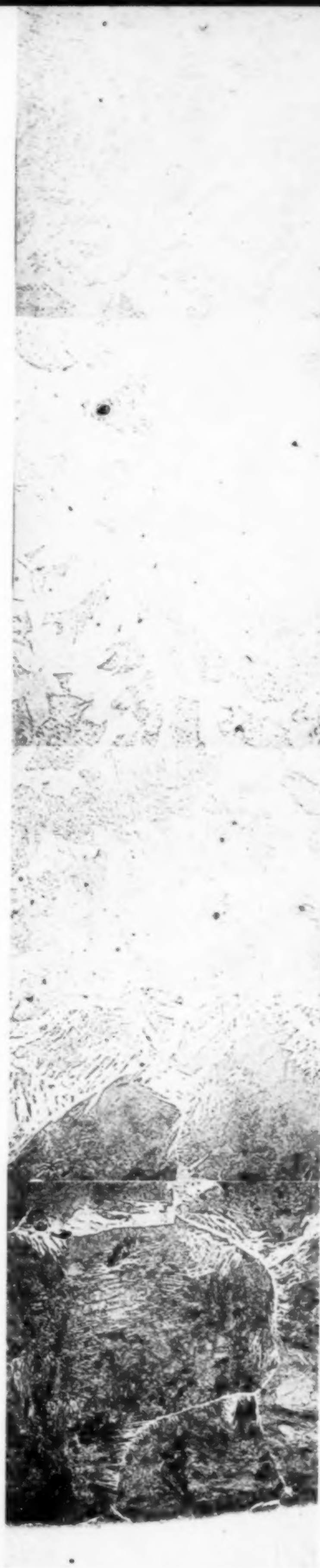
The last group of three views (page 507) shows the weld between a high speed steel containing an addition of 11.16% cobalt and 0.93% molybdenum, and a mild steel containing 1.42% silicon and 0.42% molybdenum. At the left is the condition after a commercial anneal; here we see the effect of silicon diffusing from one steel into the weld zone, and probably cobalt from the other steel. The result is a zone of clear ferrite, as obtained by Prohoroff with his aluminum-titanium steel on slow cooling. Heating our sample quickly to 2425° F. and oil quenching, results in the structure shown in the central micrograph. Large amounts of carbon appear to have diffused further and more uniformly than from 18-4-1 high speed welded

to a 0.10% carbon steel lower in silicon (page 506).

Finally, the right hand view in the group of three shows the central sample after re-annealing at 1680° F. Again we find a broad band of ferrite in the weld zone after slow cooling, but the second anneal has resulted in much greater carbon diffusion. The cobalt-molybdenum high speed steel clearly shows the loss of carbon from a layer immediately under the original electrolytic iron. We also see pearlite, absent there after the first anneal, existing in the layer nearest the carbon steel. This is perhaps due to dilution of silicon by prolonged diffusion, reproducing conditions such as seen in the weld zone in the left micro on page 506.

It is not clear why the carbon should have traveled further across the weld zone from the cobalt-molybdenum high speed steel than it did from the 18-4-1 high speed steel. However, the author is investigating the rate of diffusion of carbon from alloy steels into pure iron, and can definitely state that carbon *does* diffuse faster from a cobalt-molybdenum high speed steel than it does from an 18-4-1 high speed steel at temperatures near 1700° F.

*After Long Anneal at 1680° F.*



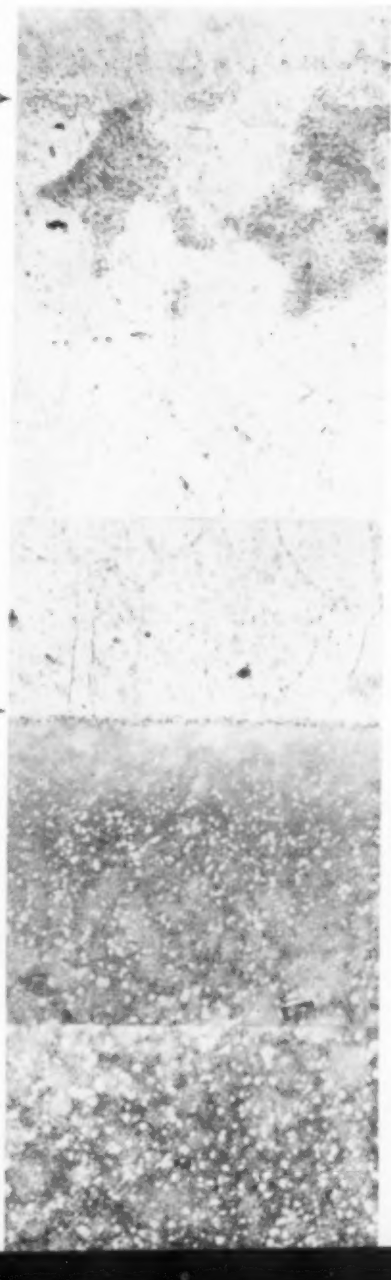
*Annealed at 1680° F., Then Oil Quenched From 2425° F.*

C 0.10%
Si 1.42%
Mn 0.26%
Mo 0.42%

Arrows mark outer limits of original electrolytic iron; center of weld identified by oxide inclusions

C 0.77%
Cr 4.16%
W 17.27%
V 1.77%
Co 11.16%
Mo 0.93%

*Annealed at 1680° F., Then Oil Quenched From 2425° F., and Re-Annealed at 1680° F.*



*Carbon Apparently Diffuses Faster From High Speed Steel Containing Cobalt and Molybdenum Than From Plain High Speed*

*Progress in iron smelting and steel refining is so dependent on improvements in refractories, and success in vitreous enameling so influenced by the underlying metal, that ceramists and metallurgists find much of mutual interest*

# Brick Makers and Metal Men Discuss Common Problems

By J. B. Austin
Kearny, N. J.
*Specially Reported for Metal Progress*

Several years ago, a chemical engineer, who had had some experience in steel plants, viewed the latter industry in the light of this experience and found it grievously wanting. What is more, he expressed his opinions publicly in an almost savagely critical paper in which he ridiculed most of the present methods and pointed out in a general way how the several processes involved in steel making could better be carried out. Had this iconoclastic gentleman attended the annual meeting of the American Ceramic Society held in New York during the week of March 21, he might have learned something which apparently was not clear to him, namely, that the failure of the steel industry to improve its processes along the lines he suggested is due as much to the lack of suitable materials of construction as to lack of initiative or imagination. He would see more clearly than ever before that many operations in the steel mill are being carried out as efficiently as is possible with refractories now available and that substantial improvement in these operations can be brought about only through improvement in the refractories or through the introduction of entirely new materials at economic cost levels. Moreover, he would almost certainly have been impressed, as many others were, by the increasingly greater amount of attention which the steel maker is giving the refractory problem, and by the sincere and serious cooperation between the makers and consumers of refractories.

The question of refractories was given special emphasis by the Ceramic Society this year by the fact that it was the subject of the important Orton Memorial Lecture, when members gather to honor the memory of the society's founder, Gen. Edward Orton, Jr. This lecture was given by Robert B. Sosman of the Research Laboratory, United States Steel Corp., and president of the American Ceramic Society, who spoke on "Pyrometry and the Steel Maker's Refractories." The theme of Dr. Sosman's remarks was that although a decade or two ago pyrometry was important only in the manufacture of refractories, its principal role today is in their preservation!

As a typical example of the usefulness of the pyrometer in this connection, he described in some detail its application for the protection of openhearth refractories. One of the chief problems here is to prevent rapid deterioration or failure of the roof which, as Dr. Sosman pointed out, is no easy job because the temperature range in which the furnace may safely be operated is very narrow. Thus, the furnace must be kept above about 1585° C. (2880° F.) in order to provide sufficient superheat for the inevitable cooling during tapping and teeming, while the upper temperature limit is fixed at approximately 1660° C. (3020° F.) by the fact that in the

presence of $Fe_2O_3$ the silica roof melts sharply at this point. The exact value of this temperature varies somewhat with the partial pressure of oxygen in the furnace but at best the safe operating range is not much more than 75° C. (135° F.) and it is a fine tribute to the skill of furnace operators that roof failures do not occur more frequently.

Prolongation of the useful life of the roof by the prevention of overheating was strikingly brought out by some data on the decrease in thickness of the roof brick during a campaign. If the roof is not overheated it loses on the average about 0.05 in. per heat. A single overheating can, however, cause a reduction of 1/4 to 1/2 in.; in other words, a single overheating, even for a relatively short time, may cause as much damage as five or ten well-controlled heats, and thus bring about a corresponding decrease in the life of the roof.

After reviewing briefly the several types of pyrometer available, Dr. Sosman described in some detail two that have been successfully employed in roof control and illustrated how they are used. The application of these methods to the more difficult problem of getting the correct temperatures of the regenerators was also discussed. He further included a brief but entertaining dissertation upon the subject of "gadgetry" or "gadgetetics" in order to demonstrate that the pyrometer should not be classed as a gadget, but is an extremely useful tool.

## High Temperature Measurement

Another interesting paper on pyrometry was presented by H. T. Wensel of the National Bureau of Standards, who gave a general discussion of the measurement of high temperatures and described the available methods and instruments, their accuracy and their adaptability to different conditions.

The Refractories Division of the American Ceramic Society joined with Committee C-8 on Refractories of the American Society for Testing Materials in sponsoring a symposium on the testing of refractories, which produced a number of papers of metallurgical interest. In fact, there were a surprisingly large number of representatives of the steel industry attending these sessions. The paper of most direct interest was given by E. E. Callinan and Gilbert Soler of the Timken Roller Bearing Co., who discussed the practical service testing of refractories in the steel plant and gave illustrations of tests conducted in the openhearth, electric furnace and pouring pits. Some of their photographs showed very clearly the severe punishment refractories undergo in the melting shop. They also touched upon the relation between length of refractory life and the economics of furnace operation and showed how the behavior of a refractory sometimes influences the quality of the steel produced. Some of the points brought out were already considered by Mr. Callinan in his article on "Pit Refractories" in METAL PROGRESS for last November.

There were several other papers in this symposium, which, though not dealing directly with metallurgical matters, contained much of value to anyone concerned with the inspection or testing of refractories in a steel plant. R. A. Heindl of the National Bureau of Standards described the Bureau's testing equipment, much of it unusual and of special design; S. M. Phelps of Mellon Institute outlined the difficulty in designing test methods, and W. C. Rueckel of the Koppers Co. discussed methods of testing refractory insulation.

Also on the Refractories Division program was a paper on "Acid Bessemer Refractories" by J. H. Chesters and R. J. McLean of the United Steel Companies Ltd. of Great Britain. As nearly as one could tell without seeing the manuscript, this is an extension of the work reported by Chesters and Lee in the *Transactions* of the (English) Ceramic Society in 1936. Chesters and McLean conclude that failure of the tuyeres, which generally precedes that of the remainder of the bottom, is due to attack by ferrous oxide and manganous oxide either of which, if present at a concentration of 8% or more, reduces the melting point of the tuyere to the temperature of molten steel. They suggest that bottom life can be prolonged by using *(a)* basic tuyeres of high spalling resistance, *(b)* plumbago (clay-graphite) tuyeres or *(c)* fireclay tuyeres of high alumina content.

J. M. McKinley of the North American Refractories Co. and S. M. Phelps of Mellon Institute presented some very useful data on the spalling of silica brick during heating and cooling. They found that, in practice, there is relatively little danger during cooling because it is difficult to cool a large furnace rapidly; on the other hand, there is considerable danger of spalling on heating, particularly on first heating, when the rate of temperature change is usually much more rapid.

There were also two papers on coke-oven

refractories. W. C. Rueckel of the Koppers Co. described in detail an unusual failure of a coke-oven wall, apparently through reaction with iron oxides in the ash from very low grade coal; it was suggested that the difficulty could be largely overcome by washing the coal before charging. A study of the thermal conductivity of silica coke-oven liners by J. B. Austin, R. H. H. Pierce, Jr. and W. O. Lundberg of the Research Laboratory of the United States Steel Corp. revealed that the conductivity varies greatly with porosity, and the higher the porosity the lower the thermal conductivity.

But the attention of the visiting metallurgists was not directed at the Refractories Division alone, for the Enamel Division also offered attractions. For example, F. R. Porter and J. H. Nead of the Inland Steel Co. described the characteristics of good sheet metal for porcelain enameling. They explained why it is that the most satisfactory base metal for enameling is one low in carbon, manganese, sulphur, phosphorus, and silicon and illustrated their points by means of thermal expansion curves and photomicrographs.

R. M. King, of Ohio State University, reviewed the chemistry of the processing of cast iron for enameling purposes. He discussed the influence of the presence of oxygen and sulphur, went into the thermodynamics of deoxidation and desulphurization and considered the relative deoxidizing power of the several elements present. He also offered some suggestions as to a possible relation between the deoxidizing and desulphurizing reactions and the blistering of enameled cast iron.

Other papers dealing with iron were presented by P. C. Stufft of the Porcelain Enameling & Mfg. Co. who surveyed the causes of rusting in cast iron during the drying of a base coat, and by R. B. Schaal of the Ferro Enamel Corp. who compared the metallographic characteristics of three irons for enameling.

The relatively few papers mentioned in this review are by no means all those that were presented at this meeting; indeed, they are not all that might be classed as of metallurgical interest for each of the 50 papers presented in the Enamel Division and the Refractories Division had an attentive audience which included metallurgists as well as ceramists. They do, however, represent the contributions of broadest scope and of most general appeal and the remainder must, from lack of space, be left to the kind offices of the regular abstract journals. (The American Ceramic Society does not in general preprint the papers presented at the annual meeting, but all are scheduled to appear in the *Bulletin* and the *Journal* of the Society.)

As a final bit of evidence to prove that the meeting was distinctly unusual, it should be reported that out of approximately 1000 people registered, there did not appear to be more than a few hundred candid camera fiends!

# Effect of Temperature on the Properties of Steels

**By Charles E. MacQuigg**

*Abstract of paper for International Association for Testing Materials, London, April, 1937*

Utility of metals at sub-zero and at moderately elevated temperatures depends on the influence of temperature on their mechanical properties; above low red heat the criterion is surface stability.

Sub-zero service occurs in aircraft, arctic exposure and refrigerating systems. Low temperatures in general increase the tensile strength but decrease the ductility and particularly the resistance to impact. If temperatures are plotted against impact resistance, a much distorted *S* form of curve is generally produced, with the rising portion nearly vertical for some steels; the problem is to find a steel with the "break" occurring as far to the left as possible. For such low temperatures, nickel, chromium, copper, vanadium and zirconium have been favorably mentioned for alloying in steels. The austenitic steels are particularly good, and for improvement by heat treatment the aluminum-killed mild steels have been attracting attention.

For service at moderately elevated temperatures the phenomenon of creep will frequently assume importance. This involves the observation of tensile tests during hundreds or thousands of hours' duration at rigorously constant temperature. While this method has been standardized by a joint research committee of A.S.M.E. and A.S.T.M., "step-down," "step-up" and "relaxation" methods have their advocates. The last-mentioned is accepted only for reconnaissance, although it does have a special appeal to users of bolts.

Stretch determinations alone are not enough information from the long-time tensile test. Phase

*(Continued on page 558)*

*Executives, salesmen and engineers, together with foundrymen and metallurgists, have a mutual responsibility in the production of bronze castings requiring strength, imperviousness or corrosion resistance, wherein soundness and uniform structure are held to be paramount to chemical composition*

# Problems in Bronze Manufacturing and Selling

In this paper, taken from addresses before the Toronto Chapter ⊛, and the annual convention of American Foundrymen's Association, held this month in Milwaukee, the original will be contracted materially by eliminating those portions that refer primarily to the foundryman's art — not because his problems do not need discussion but because the present audience is more likely to consist of metallurgists or engineers for producer or purchaser. Really, many of the purchaser's just complaints can be traced back to a fundamental characteristic of several of the useful bronzes, namely a high solidification shrinkage. The foundryman combats this by a correct placement of generous risers, frequently weighing as much or more than the casting itself, so designed that an adequate supply of molten metal exists in those masses to the very last. Cavities in these risers are often lined with beautiful crystalline forms.

The test bar is one of the most important aids to the engineer-purchaser. Our standard keel block for making specimens (page 513) is of the greatest value in setting up standard metal conditions. One must minimize the personal factor in making such tests. To this end the keel blocks are made of core sand, dried in an oven, and with no blacking applied. The gate is made from a pattern so that the height of pour, the rate of feeding (the cross-section of the gate being constant) and rate of cooling are easily maintained. The workmen must pour as closely to the sprue as possible and keep the sprue *full*.

One can then vary the casting temperature at will and it will be known that the test bars on the keel block have been perfectly fed and correctly cooled to give standard results. In the case of aluminum bronze, the keel block is quenched in cold water 15 min. after pouring, the pouring temperature being 1950° F.

Fracture of the keel bar gives perhaps the most information to the metallurgist and the foundryman of any of the tests available. A collection of such fractures of different alloys for use in any foundry is of the greatest assistance to the foundry superintendent, as he can get his results long before any physical test bars or analyses are ready. To fracture the keel bar it is sawn half way along its length, whereupon a wedge is inserted and the uncut half pried open. If desired one side of the bar can then be used for tensile test, the other for Izod, impact tension and compression. Impact tests are not used as much in the study of nonferrous alloys as they should be.

Turning now to problems that, although interesting to foundrymen, come perhaps more under the eyes of the metallurgist, let us state one as follows: "Required a metal to resist

**By Harold J. Roast**
Vice-President, Canadian Bronze Co., Ltd.
Montreal, Canada

acid attack uniformly as long as possible but particularly to be free of areas for which the acid in question has a preference."

It is a common thought that *composition* is the great criterion for such a metal. The writer is not of this opinion, believing that the molecular and crystalline structure is of paramount importance. For proof, look at the two blocks of silicon bronze on page 514. Both are of identical composition chemically but when subjected to acid attack the one corrodes away uniformly with a perfectly smooth, close surface, whereas the other shows strong evidence of preferential attack.

## Sound Structures Resist Corrosion

Remember that deep etching must be used. Metal will give beautiful crystals on light etching, free from all sign of preferential attack which on continued etching will show up badly. By deep etching is meant putting the casting into a dish containing a solution of three parts of nitric acid, one of hydrochloric and one of water, all acids being of commercial grade, and leaving it there for 10 min. It is then removed and plunged immediately into cold water, finally washed under the tap, dried and painted with clear white shellac.

When we ask why this difference in corrosion resistance should exist, we find that it is due to uneven crystal formation due to lack of feeding, to absorption of gases during melting, or to too high a temperature of pouring — any or all of these. Essentially we find the difference by fracturing the two metals; the close, even grain of the one contrasts strongly with the uneven and discolored grain of the other.

This means that in making acid resisting castings of bronze the gating, feeding and pouring temperature are all-important.

Another example of this important matter may not be amiss. The right and left views in the three on page 515 are photographs of the deeply etched cross-sections of a 3-in. bronze stick, cast 12 in. long. Composition is copper 85%, tin 5%, lead 5%, zinc 5%. Both sticks appeared entirely solid on machining or sawing. The one at left was poured in the usual way from the bottom, hot metal being poured into the riser at the top. The one at right was poured with eight gates entering each side, as in the center view, poured slowly from the bottom so that hot metal entered progressively and therefore the casting fed itself progressively. Note the uniformity of the acid attack in the one at right and the preferential intercrystalline attack in the other. The whole of each bar was similar to the area shown.

*A Metallic Chateau*
*Crystalline Forms Existing in the Shrinkage Cavity of a 400-Lb. Bronze Riser*

For anti-corrosion service the feeding of the casting is still more important on account of the fact that it enables the crystal size to be uniform. The finer and more uniform the crystals the more uniform the corrosion attack. After all, in many cases it is not a question of the metal not being attacked at all, but of the *life* of the metal under the given corrosive conditions; the more uniform the attack the longer the life.

For pressure castings, feeding to avoid internal shrinkage is the important feature. In such cases the size of the crystals is a secondary matter.

In the endeavor to get uniform small crystals a balance must be maintained between the *progressive* feeding of the casting as affected by the rate of pouring and temperature, and the feeding of the casting by the riser or risers. The old statement "the hotter the metal the better the casting" is not always correct. It is

true that the hotter the metal the more chance the risers have of feeding the casting, but if the rate of pouring is adjusted, and provision made for getting hot metal where feeding will be required, small risers will do the work and a finer crystal size generally be produced in the finished casting.

It is not enough to study the pouring temperature; the temperature of the metal as it traverses the intricacies of the mold must be thought out before the pouring temperature is finally decided upon. It must be remembered also that there are two factors that come into play, namely the rate of entry of the metal into the mold and the temperature thereof. If the former is increased the latter may be lowered, or, as is often preferable in the case of alloys forming much dross, the rate of entry may be decreased and the mold filled completely by increasing the pouring temperature.

A statement has frequently been made in connection with shrinkage that never seemed to be in accord with reason, namely that gravity pressure would make up for shrinkage and that it can be applied by using a tall sprue in place of the usual short one. It should be obvious that the gate of narrow section will solidify long before a riser of generous area, and no fluid pressure can be exerted through a solid neck no matter how high a head of metal there is above the solid plug.

### Metal Exudations or Metal Sweat

This is a problem met by foundry metallurgists, particularly in connection with architectural bronze. It is frequently not realized to what extent a metal present in a very small percentage may become a large factor, owing to segregation. For example, an architectural bronze of composition 10% zinc, 5% tin, no lead and the balance copper, will sweat beads of metal of the composition 18% tin and the balance copper, no zinc at all being present. Another alloy containing 4.4% tin, 9% zinc and 1.4% lead, balance being copper, will sweat metal which is pure lead, free from either tin, zinc or copper.

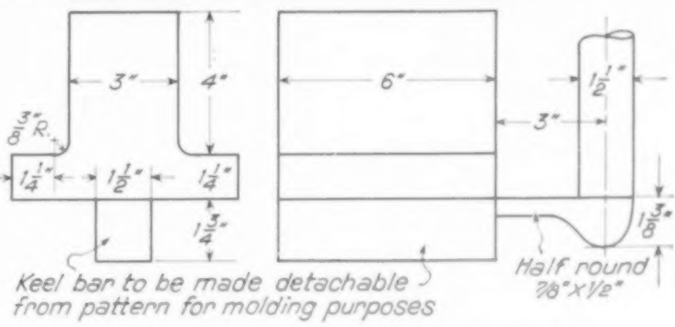
Naturally, discolorations produced by such sweating are inimical to architectural bronze that is required to have the natural metal finish without artificial coloration. The particular value of tinless or silicon bronze for architectural work lies in the absence of tin and lead, which have a proclivity for "sweating."

### Representative Tests

Designers and engineers specifying castings for important duty immediately are face to face with the problem of representative samples. This is inherent in all discussions of the propriety of cutting test bars from the castings or having test bars cast from the same pot of metal but separate from the castings.

It has to be borne in mind that the real use of a test bar is to indicate to the engineer that the molten metal put into the casting was in thoroughly good condition — that is to say that it was *capable* of giving the necessary strength expected and that it was free from gas and oxidation. It is *not* the duty of a test bar to give to the engineer the strength of the various sections of the casting itself. This is a question that must be worked out as a matter of experience, based, if it is thought the work warrants it, on tests made on the various cross-sections of the actual casting itself.

Probably there have been more unfair rejections of castings on the basis of test bars when the same have been attached to castings than from any other cause. Sometimes the casting draws on the test bar and sometimes the test bar draws metal from the casting. This is not good for either.




*The Keel Block Has a Mass of Metal Above to Insure Soundness in Test Bars*

Another thing that non-foundry engineers should remember is that composition is of less importance than foundry practice. Frequently one will find that better castings are made, for example, with scrap metal mixed with the right proportion of metallurgical brains, than from virgin metal where the cerebral addition is absent.

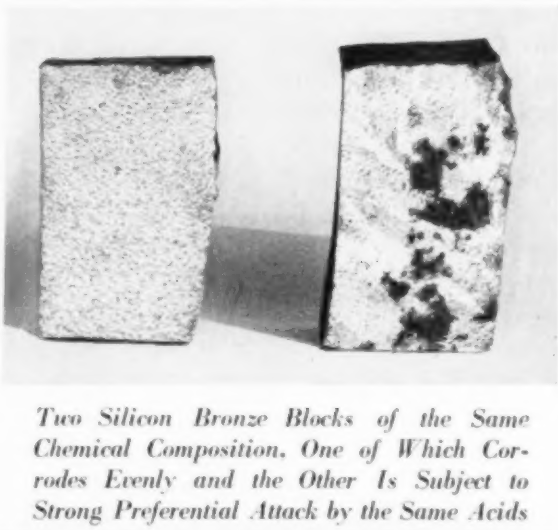
Then comes the question "Why has this casting broken?" If the casting was not sound

the answer is very easy and the engineer is entitled to say that the foundry practice was poor. On the other hand, there have been literally hundreds of cases where the real answer to the question is that the casting broke because *sound* metal was stressed beyond its ultimate strength. This is a clear bill of health to the foundry and comes back to one of two things, either incorrect design or application of a greater force than was intended by the designer.

## Relation Between Design, Pattern and Casting

The engineer generally wants strength — that is strength in the whole of any given casting. It is reasonable to assume that the useful strength is reached at a region where the relation between the actual strength of the casting and the maximum force it has to withstand bear the lowest ratio to each other. There may be parts in the casting that are actually weaker than such a region but which, under the conditions, have less strain put upon them.

In order that the engineer may attain the objective mentioned above, he must consider in his design the characteristics of the metal to be used and the practicability of producing a satisfactory casting in the foundry. This entails either a knowledge of such matters or consultation with those who have such knowledge. For instance, the matter of shrinkage characteristics of the alloy does *not* involve the shrinkage indicated on the pattern maker's rule, but the performance of the alloy where a heavy cross-section joins a light one. Many other considerations, such as the elimination of sharp angles and undercut projections, the limitations of the founding art concerning small diameter cores of considerable length, and so on, must receive attention if trouble to all concerned is to be avoided. The more consultations between the designing engineer, the pattern maker and the foundryman, the better.



*Two Silicon Bronze Blocks of the Same Chemical Composition, One of Which Corrodes Evenly and the Other Is Subject to Strong Preferential Attack by the Same Acids*

It is not uncommon for the pattern maker to be instructed to keep the machining allowance low in order to reduce the weight of the casting and therefore the intrinsic value thereof. In such manner is the door opened to false economy.

It is true that the foundry usually replaces free of charge (that is, free of *direct* charge) a faulty casting, but the engineer is put to the expense and loss of time that the machining has required. In the end, a more generous machining allowance is an economy of both time and money.

A custom that has nothing to recommend it is that of producing a pattern of improper foundry design and then, when the first foundry to which it is sent turns out a bad job, shopping around from foundry to foundry until some unlucky wight succeeds, more by good luck than good management, in obtaining *one* satisfactory casting. This immediately strengthens the purchasing agent's hand and he says to all the other foundries, "We got a good casting from the XYZ Foundry, therefore the pattern is all right." The fact of the matter is the pattern design was fundamentally wrong. Although under a fortuitous combination of circumstances one good casting was obtained, had the pattern been right all reasonably good foundries would have been able to handle it.

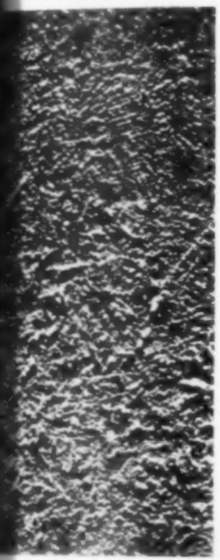
Let us suppose that the casting has been properly designed, properly "patterned" and cast, it may still be spoiled by poor machining, either by sharp angles or rough finish. Engineers of all people should appreciate the effect of these errors, due to stress concentration, the so-common cause of subsequent progressive fracture. Much has been said and doubtless much has been learned in this connection, but every day brings examples of these fundamental mistakes.

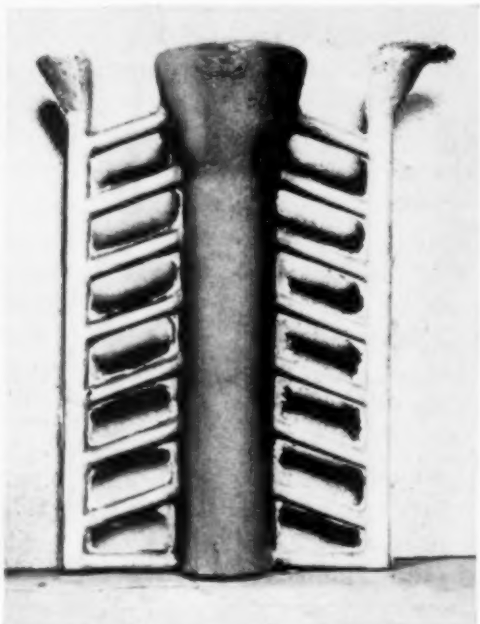
The point of view of the executive is worthy of careful study but only a passing reference can be made here. Foundry executives should realize that there is need for someone in the

foundry to have time to "ponder." The word "ponder" is used because it implies "quiet thinking over a period of time." Provision for such a person in a foundry organization of any size is essential — in fact, no matter how small the foundry, this pondering has got to be done by somebody at some time, quietly and undisturbed, possibly in the wee sma' hours.

### Hints for Executives and Salesmen

There is also need for someone to collect data and to file the same for intelligent use later. This emphasizes the fact that isolated experi-





*Bronze Bars of Same ...position Were Cast, ... Gated at Bottom and the Other From Multiple Gates. The ... exhibits intercrystalline corrosion, the second uniform attack*

ments prove of comparatively little value to a company. The benefit is really obtained by the cumulative value of the work and to obtain this cumulative value proper records must, of course, be maintained. In the company with which I am associated we have adopted the method of photographing problem castings from at least three and sometimes a greater number of angles, complete with gates and risers. These photographs are pasted on one page and the foundry procedure carefully typed out in detail on the other. In this way we get a complete and intelligent record of the steps used to obtain a satisfactory casting.

Care is necessary in the selection of problems to be studied. It really takes a broad-minded manager to authorize experiments on 800-lb. castings of expensive alloys. In my 30 or more years of foundry work it has been definitely shown that, providing the metallurgist uses judgment as to what problems are worthy of such investigation, a thorough attack of genuine commercial problems is a sound business investment.

The study of any problem presupposes the process of thinking, and if problems are to be satisfactorily solved this thinking must be logical and be associated with a determination to overcome all the difficulties that present themselves, and to never cease trying until the solution is reached. It is my opinion that a problem is not really conquered until one can produce both the bad feature that is being studied and the good condition at will. To correct a problem in metal by some process but to be unable to take that satisfactory product and make it unsatisfactory is really only to have solved half of it, and is no guarantee that trouble will not return to plague you.

*Salesman* — Turning now to the salesman's point of view, from what has already been discussed, it should be apparent that price alone is a poor criterion upon which to base a selling argument. Rather should the attitude be taken that the salesman's product is the result of superior knowledge of manufacture, honesty of purpose and economic production. It should be stated that the result of these components foots up to a certain price for the job in question, and then the purchaser should have been so convinced of the sincerity of the salesman and the necessity of these components that the price is a matter of secondary consideration.

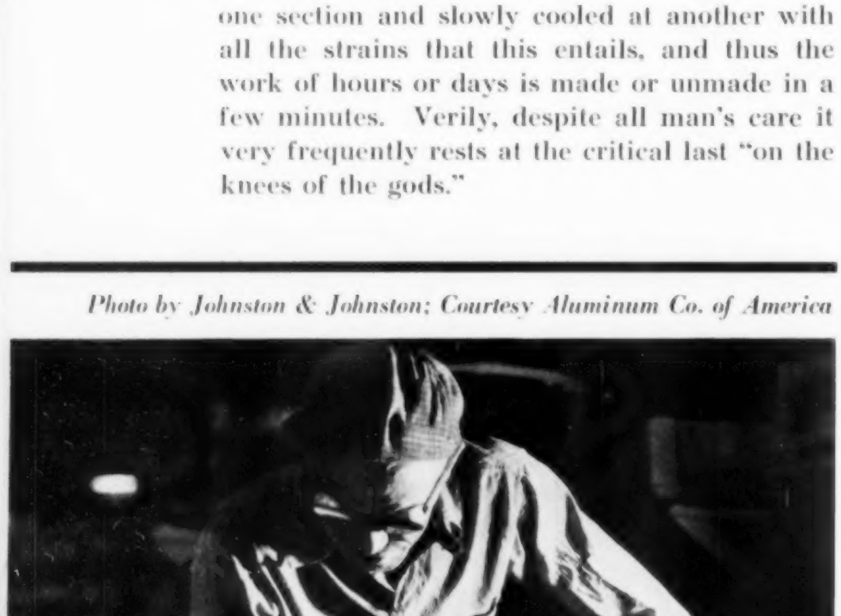
*Purchaser* — And now there remains the all-important section of those engaged in the bronze business. Without the purchaser the whole structure falls to the ground, unless it be

an institution engaged in endowed research and not in the earning of stock dividends.

The purchaser will frequently ask, "When will the casting be delivered?" The foundry superintendent will reply, "At such and such a time, providing the casting comes out all right." The purchaser immediately gets very annoyed and asks why the foundry doesn't know its job.

There is good reason for the foundryman's replying as he did. Molding is an art rather than a science despite all the scientific aids which have been developed in recent years. The superintendent's reply is reasonable because of the fact that after everything has been done that can be done, good metal having been used, the same being well melted, the mold being sound and the gating the best that is considered so for that particular casting, *then* molten metal is poured into the soft and friable sand, to rush over the fine contours, to create gas which must not be entrapped in the metal, to be chilled at one section and slowly cooled at another with all the strains that this entails, and thus the work of hours or days is made or unmade in a few minutes. Verily, despite all man's care it very frequently rests at the critical last "on the knees of the gods."

*Photo by Johnston & Johnston; Courtesy Aluminum Co. of America*



# Cast Crankshafts in England

USE OF CAST CRANKSHAFTS has progressed considerably in England, and a joint research has been under way for some time in the National Physical Laboratory, sponsored by firms and societies interested in this development. Five commercial materials have been studied, and some of the principal data are included in the table.

The alloy steel noted therein is a material especially developed for cast crankshaft purposes; the copper-chromium iron is in extensive production for high duty cast crankshafts; the inoculated iron is in active commercial development for cast crankshafts; the chromium-molybdenum iron is in production for many types of engineering products, including crankshafts; the nickel-chromium iron was especially developed as a low duty crankshaft material, of which several thousands of crankshafts for small oil and gasoline engines are in successful operation in service.

It is not so surprising that even cast iron cranks are coming into successful use. Whereas the term cast iron formerly implied to the engineer a porous, defective, and somewhat unreliable material, low in tensile strength and design, today alloy gray cast irons, "as cast," are capable of yielding tensile strengths of 60,000 psi. and of further improvement by heat treatment, while the heat treatment of chill-cast material produces strengths up to 130,000 psi.

These figures do not tell the whole story, for the stressing requirements demanded of a satisfactory crankshaft material include good static torsional and bending strength, allied with marked resistance to cyclic bending and cyclic torsional stresses and to combinations of these, together with freedom from marked notch sensitivity under cyclic stressing in relation to stress concentration effects. Wear resistance is also essential, while a low value of Young's modulus

By H. J. Gough

*Abstracted from "Properties of Some Materials for Cast Crankshafts," British Institution of Automobile Engineers, March, 1937*

*Metal Progress; Page 516*

## Properties of Cast Alloys Used for Crankshafts

| Property | Alloy Steel (A) | Copper-Chromium Iron (B) | Inoculated Iron | Chromium-Molybdenum Iron | Nickel-Chromium Iron |
|---|---|---|---|---|---|
| Composition | | | | | |
| Carbon (total) | 0.32 | 1.56 | 2.75 | 3.28 | 3.36 |
| (graphitic) | | | | 2.47 | 2.39 |
| Silicon | 0.23 | 1.16 | 1.59 | 2.19 | 1.22 |
| Manganese | 0.88 | 0.44 | 0.88 | 0.95 | 0.92 |
| Sulphur | 0.04 | 0.05 | 0.07 | 0.10 | 0.11 |
| Phosphorus | 0.03 | 0.07 | 0.08 | 0.17 | 0.12 |
| Nickel | 2.42 | tr | .... | .... | 1.87 |
| Chromium | 0.49 | 0.46 | .... | 0.42 | 0.47 |
| Molybdenum | 0.38 | .... | 0.29 | 0.95 | .... |
| Copper | 0.13 | 1.75 | .... | .... | .... |
| Brinell hardness | 260 | 260 | 245 | 280 | 265 |
| Izod impact, ft-lb. | 24.8 | 1.2 | 1.5 | 0.8 | 0.4 |
| Tensile properties | | | | | |
| Proportional limit, psi. | 70,000 | 35,000 | 5,500 | 5,500 | 5,000 |
| Yield stress | 98,000 | none | none | none | none |
| Ultimate stress | 118,000 | 72,500 | 52,000 | 46,500 | 42,000 |
| Elongation ($l = 4\sqrt{A}$), % | 10.0 | 0.2 | 0.4 | 0.8 | 0.8 |
| Reduction of area, % | 16.0 | 0.0 | 0.4 | 0.0 | 0.0 |
| Modulus, psi. $\times 10^{-6}$ | 29.3 | 26.8 | 21.7 | 20.1 | 18.7 |
| Torsional properties | | | | | |
| Proportional limit, psi. | 38,500 | 35,000 | 9,600 | 6,000 | 6,000 |
| Rupture stress, psi. | 105,000 | 86,500 | 71,500 | 73,000 | 47,000 |
| Total twist ($l \div d = 8.3$), deg. | 846 | 96 | 82 | 53 | 16 |
| Modulus, psi. $\times 10^{-6}$ | 11.5 | 11.4 | 8.6 | 8.6 | 7.1 |
| Fatigue in bending | | | | | |
| Endurance limit, psi. | ±60,000 | ±40,500 | ±29,000 | ±24,000 | ±23,700 |
| Ratio to tensile strength | 0.51 | 0.56 | 0.55 | 0.52 | 0.56 |
| Fatigue in shear | | | | | |
| Endurance limit, psi. | ±40,000 | ±32,000 | ±25,500 | ±24,500 | ±20,000 |
| Ratio to rupture stress | 0.34 | 0.45 | 0.49 | 0.52 | 0.47 |

(A) Cast 6-in. billet annealed at 1575° F. Test pieces then oil quenched from 1550° F. and tempered at 1200° F.

(B) Heated to 1650° F. for 20 min., air cooled to 1200° F., reheated to 1400° F. for 60 min., furnace cooled to 1000° F., thence in air.

is an advantage when cases arise of non-alignment of bearings.

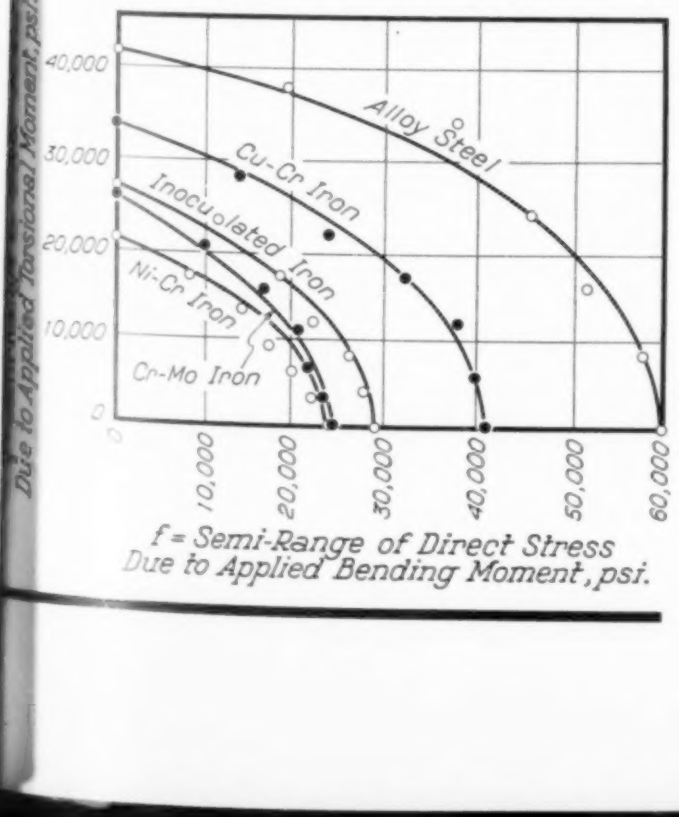
In the present studies test pieces were cut from separately cast blocks. The supervising committee record their considered opinion that the results obtained do, in fact, afford fair representations of the properties of the materials examined.

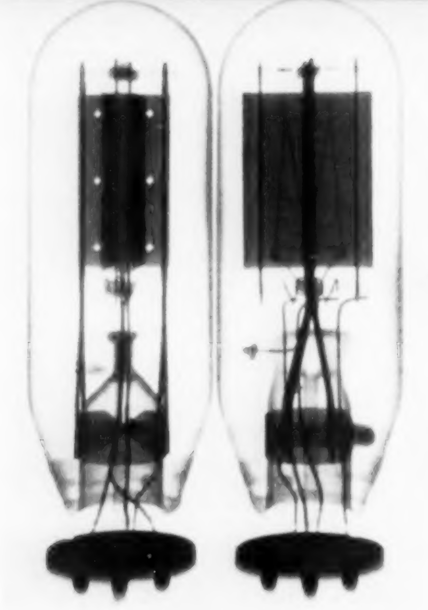
Aside from information on alloys used in Great Britain, the report gives data on endurance under combined stresses. A high speed machine has been developed capable of imposing either plain bending or torsional shear, or any combination of the two. Figures for performance under the combined fatigue stresses represent a new field of investigation, and are plotted in the curves below. The fatigue limit of each material was determined, by the usual endurance method, on a $10^7$ cycles basis, under the following seven stress conditions: Reversed plain bending stresses, reversed shearing stresses, also five combinations of these stresses in which the ratio of range of bending stresses to range of shearing stresses had the values of 0.268, 0.577, 1.000, 1.732, and 3.732.

In the diagram, the area below and to the left of each curve encloses all stress combinations which will not damage the alloy represented by the line in question. Obviously the intersections of each curve with the axes represent fatigue limits in simple stress, either bending or shear, as the case may be.

As the fatigue limit is usually related to the tensile strength, it is of interest to examine the values of the endurance ratios of the present materials. The relevant data are abstracted in the table, from which it is seen that although the tensile strengths vary widely, yet the endurance ratios for bending stresses show no marked variations; the endurance ratios for torsional stressing have a much greater variation due to the relatively low value recorded for the alloy steel. But the general conclusion emerges that the fatigue resistances of all five materials are high in relation to their tensile strengths, especially when it is remembered that, owing to variations from sample to sample, and casting defects emphasized by the small sizes of the cast bars, the values obtained may not represent the optimum properties of which the materials are capable when produced in the sizes and under the casting conditions of full-sized crankshafts.

*Curves Show Limiting Values for Combined Stresses in Plain Bending and Simple Shear for the Respective Materials Where Fatigue Failure Will Occur. Safe combinations lie below and to left*





*X-Ray View, Courtesy "Electronics"*

# Metal in Vacuum Tubes

Under the guise of physics and electronics, a new branch of metallurgy has developed which is concerned with the behavior of metals in vacuum and at high temperatures, and in which the mechanical properties of metals at room temperature are of secondary significance. Much fundamental research is being conducted on the surface phemomena of metals intimately related to their molecular and atomic behavior under vacuum and high temperature. Some of these data have been translated into our well-known vacuum tube devices.

It should be interesting to examine those metals which are of special significance to the vacuum tube, and the methods of processing them to render them fit for such application. The number used is quite large, and the majority of them are rare and unheard of in every-day practice and commercial application.

The fundamental observation underlying most present-day electronics was made in 1885, and was termed the "Edison effect" — namely, that current passed from a glowing carbon filament in an exhausted bulb to a separate metal plate within the bulb, if the plate were connected to the positive terminal of a battery, no matter how high the vacuum within the bulb. It was some years afterward that the "Edison effect" was explained by assuming the passage of particles of electricity from the hot filament to the metal plate. Thermionic emission, so called, is a fundamental feature of every vacuum tube, and the immediate interest of this paper is the question: "What metals are the best emitters?"

By J. Delmonte
Electrical Engineer
Akron, Ohio

One must picture the surface as covered with a blanket of interweaving electrons, traveling about at various velocities. Imagine a potential barrier preventing these electrons from escaping unless they receive considerable surplus energy (as by thermal agitation). This measure of surplus energy is called the "work function," and it has been measured by such investigators as Compton, Langmuir, Becker and Dushman. By definition the better electron emitters have lower work functions.

The melting point establishes a very definite limit, as the emission is a function of the temperature, and relatively high temperatures must be reached to attain large emissions, even though the work function is small. High temperatures also introduce problems of gas evolution, loss of strength and heat radiation, discussed in greater detail later.

## Directly Heated Cathodes

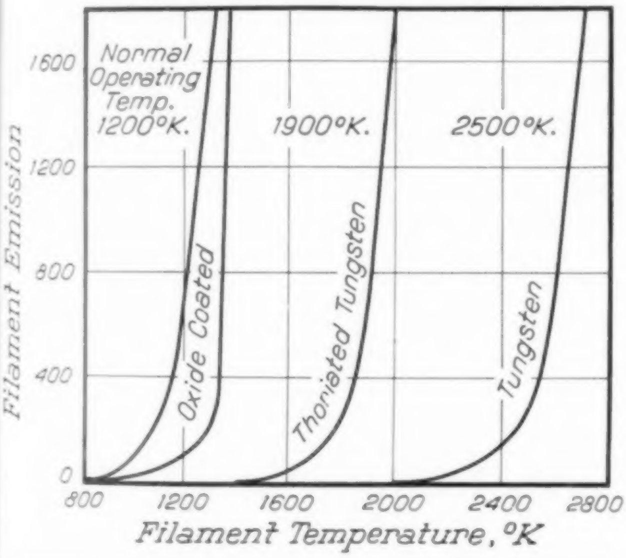
It is necessary to distinguish between the directly heated and the indirectly heated cathode. The directly heated type is of early origin, when the majority of radio tubes were operated from batteries. They are characterized by an almost instantaneous operation. The various metals playing an important part in the filament or heater are discussed in turn hereinafter.

*Tungsten* is one of the most useful cathode metals for vacuum tubes of all sorts, including the X-ray tubes. Its specialized metallurgy has been outlined frequently in the literature — see, for instance, W. P. Sykes in Metal Progress for March, 1934. With tensile strength as drawn wire up to 500,000 psi. and a melting point of 3370° C., it represents the strongest metal available with the highest melting point. In particular, the high melting point stands it in good

stead; because of its high work function it is necessary to operate tungsten filaments at very high temperatures. Tubes using it therefore require relatively large amounts of power. Pure tungsten, though replaced in filaments in smaller vacuum tubes, is used almost exclusively for high power work and high plate voltages used in transmitting tubes; a very sturdy construction is necessary, particularly at the high temperatures of operation.

*Thoriated Tungsten* — Thorium oxide particles in tungsten wire obstruct crystalline

*Owing to Its Stable Surface and High Work Function, Tungsten Requires Very High Temperatures for Adequate Electron Emission. Thoriated tungsten can be operated 600° C. lower, and oxide coated filaments 700° lower yet*




growth in electric light filaments, and it has been found that from 0.75 to 2.00% of this substance, well mixed with the powdered tungsten before sintering, reduces the work function from 4.5 volts to 2.6 volts. The thoriated tungsten filament is activated by heating the emitter to a temperature of 2600 to 2800° K. (4300° F.) for 2 min., followed by heat treatment at 2100 to 2200° K. (3400° F.) for several minutes. It is believed that thorium atoms migrate from the interior of the filament and form a mon-atomic layer on the surface. Excess voltage (or temperature) will evaporate the thorium, leaving bare the less active tungsten surface. The accompanying set of curves shows representative values. Other materials, as boron nitride, silica, and vanadium, improve the electron emission when alloyed to pure tungsten. However, thorium has proven to be the most satisfactory metal for an activator.

*Oxide Coated Filaments* — For the great majority of low-powered, low voltage vacuum tubes in small radios, oxide coatings of barium and strontium are placed on the surface of a suitably prepared filament of nickel, silicon-nickel, cobalt-nickel or "Konal." (This last-mentioned alloy, a 4 to 1 nickel-cobalt alloy with 10% ferrotitanium, was developed by Lowry and assigned to Westinghouse.) For a long time, platinum and platinum-iridium appeared to be the most satisfactory in life, strength, and emission, when used as a core for the oxide coatings, but by 1925, the greatly increased demand for vacuum tubes instigated research for cheaper and equally satisfactory metals. What is sought for is an alloy that draws satisfactorily into fine wire, operates at low temperatures and is non-sputtering, of high strength and electrical resistance when hot, and low in cost.

The electron emission of the oxide coated cathodes arises from a layer of metallic barium or strontium on the surface of the oxide. To activate this coating, the core is usually heated for several minutes in controlled atmosphere to a temperature of 1500° K. (2250° F.) and then subjected to a high frequency discharge. They operate very efficiently and require compara-

**Work Functions and Melting Points of the Metals**

| Metal | Work Function | Melting Point |
|---|---|---|
| Platinum | 6.0 volts | 1755° C. |
| Nickel | 5.0 | 1452 |
| Gold | 4.8 | 1063 |
| Silver | 4.7 | 961 |
| Iron | 4.7 | 1535 |
| Chromium | 4.6 | 1510 |
| Tungsten | 4.5 | 3370 |
| Molybdenum | 4.4 | 2625 |
| Tin | 4.4 | 232 |
| Tantalum | 4.1 | 2850 |
| Copper | 4.0 | 1083 |
| Thorium | 3.4 | ... |
| Zirconium* | 3.1 | ... |
| Aluminum | 3.0 | 658 |
| Thorium* | 2.6 | ... |
| Uranium | 2.8 | ... |
| Barium | 2.4 | 850 |
| Calcium oxide | 2.2 | ... |
| Sodium | 1.9 | 97.6 |
| Caesium | 1.8 | 26.4 |
| Rubidium | 1.8 | ... |
| Potassium | 1.8 | 62.5 |
| Caesium* | 0.72 | ... |

*Monomatomic layer on tungsten.

## Characteristics of Metals Commonly Used in Vacuum Tubes

| Property | Tantalum | Tungsten | Molybdenum | Platinum | Copper | Nickel |
|---|---|---|---|---|---|---|
| Atomic number | 73 | 74 | 42 | 78 | 29 | 28 |
| Density at 20°C. | 16.6 | 19.2 | 10.2 | 21.5 | 8.9 | 8.9 |
| Tensile strength, psi., hard drawn | 130,000 | 490,000 | 260,000 | 53,000 | 62,000 | 155,000 |
| annealed | | | | 35,000 | 35,000 | 76,000 |
| Brinell hardness, hard drawn | 75 to 125 | 290 | 147 | 90 | 94 | 83 |
| annealed | — | — | — | 35 | 40 | — |
| Melting point, °C. | 2850 | 3370 | 2620 | 1755 | 1083 | 1452 |
| Boiling point, °C. | 5300 | 5900 | 3700 | 4300 | 2300 | 2900 |
| Coefficient of expansion per °C. $\times 10^{-6}$ | 6.5 | 4.44 | 5.45 | 9.0 | 17 | 12.8 |
| Electrical resistivity at 20°C., microhm/cm.$^3$ | 15.5 | 5.51 | 5.7 | 10.0 | 1.72 | 6.4 |
| Work function | 4.1 | 4.5 | 4.4 | 6.0 | 4.0 | 5.0 |

tively little electrical power. Much time and effort has been put in their development, and the methods of applying and activating the coatings are usually held secret. The lower operating temperatures of oxide coated cathodes have been helpful to vacuum tube design, for less filament distortion, as a result of lower temperatures, has meant smaller clearances.

*Tantalum* — Before the development of ductile tungsten filaments, tantalum was used in cathode tubes. While pure tantalum wire is not suitable at high temperatures for high voltage transmission because of its low strength, it is proposed for high power transmitting tubes in the form of tantalum-clad tungsten. There are some advantages of cleanliness and corrosion resistance.

*Molybdenum* — Since other metals have exhibited superior characteristics for filament wires or ribbons, molybdenum has found little use as a filament wire, although it is used extensively in X-ray tubes. It is also useful as supports and anchors for heavy tungsten filaments which must retain their tension during their life. Molybdenum welds readily enough to other metals, but not so readily to itself. Prolonged heat treatment at 1325° C. will lower the work function materially.

Physical characteristics of these metals are compared in the table taken from a pamphlet published by the Fansteel Metallurgical Co.

Much that has been said about the thermionic emissive characteristics of the directly heated cathode will apply to the indirect type, which was developed to meet the requirements of "all-electric" radio, operating from a 110-volt a.c. house circuit. The hum resulting from alternating currents was eliminated by the indirect heater. The cathode consists of a thin metal sleeve with oxide coated surface, placed outside a heater filament of tungsten wire, the two being insulated by a temperature resistant dielectric. The tungsten wire is moderately heated by resistance, and the heat is conducted to the metal sleeve on which the emissive coating lies. The inoperative period of heating up has been substantially reduced (to, say, 10 sec.) by spraying a thin coating of alumina on the heating wire, thus reducing the mass of insulation to be penetrated.

Oxide coated nickel or nickel alloys, already discussed, are favored for the sleeve cathode. An oxide coated emitter is always employed in the indirect heater types, as too high temperatures are required by other emitters. A good example of the modern radio tube is shown on page 521. In this figure a small helical-shaped heating wire (28), surrounded by an insulating material, activates the oxide coated cathode sleeve (27 and 29).

### Construction of Grids

Before explaining the significance of the term *grid* in vacuum tube terminology, it is necessary to go a little into the historical background. Fleming is credited with the development of the di-ode or two-element (cathode and anode) vacuum tube in 1904. In 1906, De Forest conceived the idea of using a lattice-shaped wire between the filament and plate for the purpose of controlling the electron flow; it got its name from its resemblance to a roaster grid. The spacings are wide enough to permit easy passage

of the electron stream to the anode, yet the grid will control the flow of electrons by reason of its effect upon the space potential between the cathode and anode.

There are now in existence vacuum tubes with many types of grid structures, some having several to fulfill certain functions. A good example of several grids within one vacuum tube is the phantom view. Items (6), (7) and (8) are the screen, suppressor, and control grids, each a helix of fine wire, widely spaced and positioned between anode and cathode. A large number of metals have been used for grid wires, like molybdenum, tantalum, nickel, nichrome,


*Phantom View of RCA All-Metal Radio Tube*

manganese-nickel and iron. Other alloys, such as beryllium-copper, have been used in the grid structure, both in the windings and supports. Molybdenum is widely used for grid and nickel for supports. Molybdenum is rigid and non-distorting and emits very few disturbing electrons at operating temperatures; the nickel support is inexpensive, soft, ductile and has high thermal conductivity.

A typical screen grid has a mesh of 60x60 wires to the inch, with a wire size of 0.007 in. In some of the more recent radio tubes, the grid wires have been covered with carbon to increase heat radiation. Because of their nearness to the cathode, some of the activating oxide may sputter on the grid wires, and the latter, heated by radiation from the cathode, may in turn emit electrons and hamper proper functioning of the tube. In general, grids should be of high purity metal, free from occluded gases or other detrimental substances.

## Plates or Anodes

The plate or anode, recipient of the stream of electrons from the cathode, warrants careful processing. In the smaller sized tubes, metal plates are widely used, either rectangular or cylindrical in shape. In the larger power tubes, graphite anodes are rapidly being adopted. Bombardment of the plate with electrons increases its temperature, and in order to radiate this as fast as possible, carborundum blasting and carbonizing are resorted to. By carbonizing (sooting) the metal plate, the heat emissivity is improved, as it brings the plate nearer to the ideal heat radiator, a perfect black body.

Carbonization is a problem for the tube builder. A group of carbonizing furnaces is shown on page 522. A number of anodes are placed in a trough and inserted in the furnace tube, where hydrocarbon gas is allowed to play over them and deposit carbon or soot from the decomposing gas. As everyone knows who has done any case carburizing of steel with gas, the characteristics of the carbon deposit depend upon the composition of the gas, its temperature, and the nature of the metal surface that catalyzes the decomposition. All of these must be under control to produce the correct sooty deposit on tube parts.

Many metals are available for anode plates, conforming to the following requirements:

1. Low gas content.
2. Uniformity.
3. Workability.
4. High thermal emissivity.
5. Good electrical conductivity.
6. Low vapor pressure at processing temperature.
7. High work function.
8. Reasonable cost.

*Nickel* — This metal is used extensively as a plate for small vacuum tubes. It is carbonized as outlined above. Nickel will not withstand the high temperatures that other materials will, and to prevent sagging it is frequently strengthened

with ridges. Nickel must be degassed at a lower temperature than other materials. Its initial gas content is reported to be the same as that of molybdenum, which is appreciably more than that present in the typical tungsten plates.

*Molybdenum* — In the degassing operation, heating to 1740° C. (3150° F.) liberates most of the gases, though degassing at 1400° C. will be suitable for a plate to operate at 1000° C. It is impossible to remove all the gas by heating to very high temperatures, because then some of the metal will evaporate and subsequently deposit itself upon the glass electrode holders, thus changing the characteristics of the tube. Nevertheless, molybdenum is used in power tubes rather than the more costly tungsten. Warping occurs at high temperatures, necessitating adequate bracing. The heat radiation qualities are not so good, even with a carborundum blasted surface. (As the plate voltages increase, the carborundum blasting supplants carbonizing, as the liberation of gases from carbon is more serious at high temperatures.)

*Tantalum* — Though one of the more expensive metals, tantalum has been used for anodes, particularly by manufacturers abroad. Advantages claimed to offset the cost differential are that it possesses a lower vapor pressure than molybdenum; it is easier to fabricate than tungsten; it is stable in dimension after strong heating in vacuum; and it may be pretreated chemically to remove all surface impurities thus shortening the time for exhausting and degassing the tube. It becomes brittle and fragile when heated in hydrogen.

*Tungsten* — The qualities of low gas content, low vapor pressure, high strength when hot are in the favor of tungsten. Degassing operations at a temperature of 2100° C. (3800° F.) will rid the metal of the major portions of gases detrimental to tube operation. (See the article "Gas-Free Metals Used in X-Ray Tubes" by Messrs. Coolidge and Charlton in METAL PROGRESS, November 1933.) However, objections exist in the difficulty of machining and working, and the comparatively high cost.

*Iron* — Iron, ranging in purity from extra soft steel through Armco ingot iron to "chemically pure" iron (99.92 to 99.96%) is an inexpensive and satisfactory material. A brand of the latter has been commercialized by a Swedish firm under the name "Svea Metal," and is said to be quite free from occluded gases, and to have a high heat resistance. The procedure for processing this metal differs from the methods adopted for other anode materials; a thorough discussion of this point has been given by McMaster in *Radio Engineering*, March 1935. In some cases it has been necessary to carbonize pure iron for improving the heat dissipating qualities of the plates. Transmitting and rectifier tubes have utilized 99.9% iron; perhaps the outstanding success has been with the mercury type rectifiers, for the metal will not amalga-

*Battery of Furnaces for Depositing Soot on Tube Parts by the Decomposition of Hydrocarbon Gas at Moderately High Temperature. Courtesy RCA*

mate with mercury. For transmitting tubes, sandblasting of the plates is a common practice, and special precautions are necessary to avoid abrasives that will contaminate the metal.

*Copper* — Copper anodes have been extensively used in high powered transmitting tubes rated at a few kilowatts or higher, and in X-ray tubes. The same requirements of purity of metal and freedom from gas are in vogue, as with other materials in the vacuum tube. (See the above-mentioned article by Coolidge and Charlton.) In the transmitting tubes an anode of drawn copper is sealed to the glass (copper oxide will dissolve in glass) and is made part of the vacuum envelope. In some of the power types, fins are attached and cooled by an air stream. Operation at temperatures of 300° C. (600° F.) is not uncommon. In taking advantage of the excellent heat conductivity of copper, a number of the transmitting tubes have water-cooled anodes, which will permit great tube output. The construction of glass-to-metal seals becomes very difficult in such cases.

*Graphite* — No discussion of anode materials is quite complete without calling attention to the fact that graphite anodes are rapidly coming to the fore as competitors to metal anodes in power tubes of medium size, cooled by natural radiation. With an increase in emissivity, the resulting temperature of the envelope is lowered. The thick walls of graphite, required for mechanical strength, resist warping at high temperatures. The problem of adsorbed gases assumes major importance, as initially about ten times as much gas is present as on molybdenum anodes. Though graphite has been used successfully in mercury rectifiers, it was not until recently that applications were made to transmitting tubes.

## Miscellaneous Tube Metal Parts

The anode, grid, and cathode are the major parts of the vacuum tube, but a number of smaller accessories are of special significance. The all-metal sheath, a comparatively recent development, replaces the glass envelope of the vacuum tube. (The spray shield tube, developed in 1932, anticipated the all-metal sheath; it was made by sandblasting the glass envelope and spraying it with a special zinc alloy.)

The steel sheath has been heralded with much favorable comment; it was clearly described in Metal Progress, December 1935. In it the lengths of the leads have been shortened and the over-all dimensions are smaller than an equivalent tube with glass envelope. Other advantages of the all-metal tubes are that the outside steel shell serves as a shield against radio frequency disturbances, and they have a lower grid-to-plate capacitance.

Of major importance is the technique for sealing and insulating each lead as it is brought out from the tube. The problem is solved with a small glass bead in an eyelet of metal having almost exactly the coefficient of expansion as the glass up to annealing ranges. The leads tend to center in the middle of the glass bead, which, on hardening, provided an air-tight seal. The analysis of the metal (variously termed by its various makers "fernico," "kovar" and "sivar") is closely adjusted to the glass it is to match. A published composition of fernico is 54% iron, 28% nickel, 18% cobalt.

The wire supports for the electrode structure are specialized in several respects, such as purity of the material, freedom from gas, ease of attachment, and the technique of passage through the glass seal-off stems. Platinum was used at one time as a lead-in wire; less costly copper-clad 42% nickel steel wires, which could be welded to the electrodes, have been found to be satisfactory. Nickel-clad wires have given good results. Alloys of molybdenum and tungsten are used as supporting rods and lead-in wires through other special glasses.

"Getters" fulfill an important function. It is the usual practice to flash a small quantity of a substance which will combine chemically to remove the small amount of residual gas left in the vacuum tube. Consequently, getter and getter-cups for holding the substance are contained within the vacuum tube. Magnesium is much used as a getter, as it is readily volatile and will react with objectionable gases. Calcium, aluminum, barium, strontium, and phosphorus have also been used for this purpose, and sometimes an iron-cerium alloy.

For getter cups, eyelets, supports, bases and other small tube parts a wide choice is available. Nickel, molybdenum, and iron are among the most popular for these parts.

It is surprising to note that vacuum tubes draw upon so many metals for their constituents, particularly those that are not dealt with on a large scale. Other metals with which industry is most familiar appear in new form, specially processed. Much of the success of the radio industry has been due to the intensive research for suitable materials.

*Bethlehem Steel Co. is making 60 tons of wire a day by a process wherein zinc is leached from ore by sulphuric acid and deposited 99.9% pure on the steel wire in its passage through an electrolytic cell*

# Ductile Zinc Coating Deposited on Wire by Electrolysis

ZINC, as is well known, is a very desirable and inexpensive metallic coating for plain steel. It is not only quite resistant to atmospheric corrosion, but even when the surface layer is perforated the remaining zinc protects the bare iron fairly well by "sacrificial" action until most of it has disappeared. To counterbalance these excellent properties is the circumstance that difficulties increase as one attempts to thicken, evenly, the coating of pure zinc by any of the older methods, and it is well established that its life is directly proportional to its thickness. Likewise, impure zinc coatings (especially when approaching the upper limit of thickness) are brittle; coated sheet cannot be bent sharply or wire tightly woven without damage to the continuity — and life — of the protective layer.

Any proposed improvements in zinc coated steel wire, sheet, tubing or machine parts should aim to cure one or more of these limitations, and produce a uniformly thick, non-porous and tightly adherent layer of purer zinc.

Conventional methods of applying zinc coatings are three in number: Galvanizing, electro-deposition and sherardizing. Their relative importance is in that order. In the galvanizing process the cleaned steel is dipped in a bath of molten zinc and the excess metal clinging to the surface when it emerges is wiped or shaken off. Electrolytic deposits of zinc are commonly made from sulphate or cyanide solutions, the clean steel being the cathode and the anode being bars of commercial zinc. In sherardizing, the steel parts are enclosed in a rotating retort with zinc dust and powdered charcoal and heated to about 600° F.

**By Ernest E. Thum**
Editor, Metal Progress

It is important to note that the *bond* between coating and underlying steel is different in each of these three processes, as is also the *nature* of the coating.

The molten zinc in the galvanizing bath — no matter how pure an ingot at the outset — rapidly becomes saturated with iron washed away from the enclosing pot and the work going through. Likewise certain alloys are added to give the surface the desired luster and crystalline spangles. (See notes on Mr. Brayton's article on this subject on page 503.) The very surface is therefore zinc with up to 4% of alloys and the intermediate layers are somewhat stratified, brittle, iron-zinc compounds.

Electrodeposited zinc is very much purer; its attachment to the base steel involves no intermetallic compounds but something more like atom-to-atom bonds, and depends on certain characteristics of the electrochemical process. Likewise, it has been difficult to build up layers of zinc much thicker than 0.3 oz. per sq.ft. by methods commonly known and practised by electroplaters.

Surfaces formed in the sherardizing process

are iron-zinc alloys containing up to 10% iron, except at the outside where a very thin layer of purer zinc dust has been mechanically attached. As sherardizing is a cementation process similar to case carburizing of steel, the thickness of the coat increases with time and temperature; commercial limitations usually keep both at a minimum.

This brief reminder of salient features of the present state of the "galvanizing" art (using the term galvanizing broadly to include the three commercial methods) will be all that is necessary to justify, in the reader's mind, the attempt by Bethlehem metallurgists to adapt the most advanced ideas on electrodeposition of zinc to the coating of steel wire. As a matter of fact, electrogalvanizing of round wire had received much attention in Continental Europe; at least 50 wire drawing plants have proprietary installations for this purpose, some of them 30 years old. Most of the wire so produced has a very thin coat of zinc (0.3 to 0.5 oz. per sq. ft.) — all that was necessary to compete in quality with the hot galvanized wire of about double the surface thickness. In America, operations on wire were confined to an equally thin coating on flat wire and fairly narrow strip, this being usually a more economical method than hot dipping, which could produce satisfactory edges only at unusual expense for wipers. Of course, much electrogalvanizing was done on small parts in barrels and smaller tanks, and on electrical conduit.

Enormous advances have been made since the War in the production of electrolytic zinc of the greatest purity — 99.99% or better. This purest zinc has unusually good ductility and therefore, if it could be deposited tightly on the steel wire, would prevent cracking and peeling when the wire would be woven into fencing, or in other operations involving severe bending and twisting. (It may be mentioned in passing that many complaints about the short life of galvanized fencing are due, not to the fact that a thin coating of zinc was added to cheapen the article, as much as to the fact that thicker coatings would crack and flake at the sharp bends, thus offering ingress to corroding agents and destroying any anticipated improvement in durability.) Likewise this pure zinc procurable by electrodeposition is so very resistant to acids in comparison with the less pure commercial spelter that it is difficult to avoid the hopeful belief that it would also be superior in its resistance to *atmospheric* corrosion.

Technique and engineering details concerning the production of electrolytic zinc have been successfully solved, as is outlined in the editorial on page 497. It therefore appeared likely that sound deposits could be rapidly made on steel wire. To determine this point, experiments were started at the Sparrows Point plant in 1928 under the direction of U. C. Tainton, one of the pioneers in electrolytic zinc. By the year 1933 this pilot plant was producing a salable product, and the Bethlehem management decided to build a much larger department in the Cambria Plant at Johnstown, Pa. It is now in steady operation at a capacity of about 60 tons of zinc coated wire per day. The product has been christened "Bethanized Wire and Fencing."

While details of equipment vary in the many large plants now producing electrolytic zinc, the fundamental operations are the same. The concentrated sulphide ore is roasted to convert the greatest possible amount of zinc into a soluble oxide, and the least

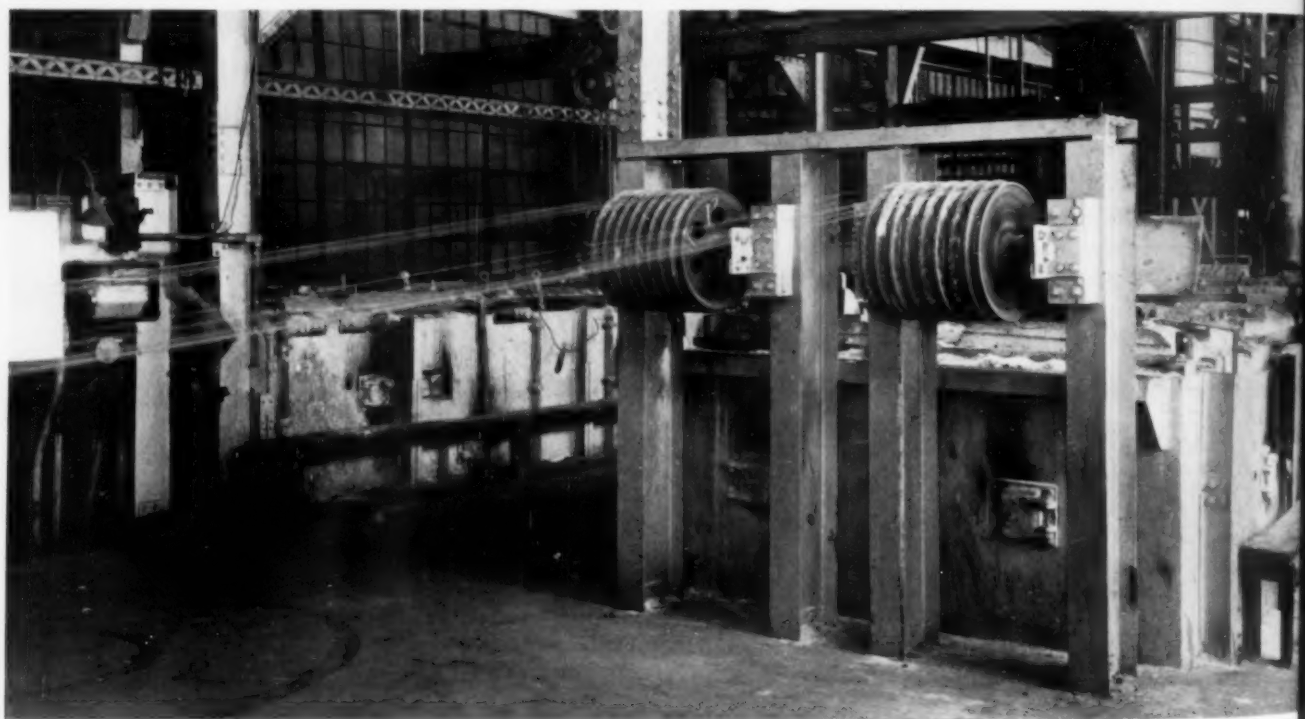
*Some of the Chemical Plant Necessary to Prepare a Pure Solution of Zinc Sulphate. Purification vats, filters, pumps and storage tanks are in view*

amount of other metals into soluble form. This roasted ore is then leached in the sulphuric acid solution returning from the tanks, and the pulp filtered and washed. The clear solution is then purified of interfering elements (and they are many), refiltered, and then is cascaded through the electrolytic tanks. Each of these contains, electrically connected in parallel, a number of anodes (sheets of insoluble silver-lead) and cathodes (sheets of clean aluminum). Direct current at proper voltage and amperage deposits a uniform layer of zinc on the aluminum, regenerates an equivalent amount of sulphuric acid, and liberates oxygen gas at the lead anodes. At intervals of say 48 hr., when the deposit has reached economical thickness, the cathodes are withdrawn long enough to strip the zinc from the two faces of the aluminum sheet. The zinc is then carefully melted and cast into ingots or slabs as the market requires.

Although it is obvious that the deposition of zinc directly on wire would save the expense and metal lost in the conversion of the cathode crystals to salable metal, the general process outlined above is different from the process now to be described in at least two respects. First the zinc must be deposited with great rapidity, else the tanks would be entirely too long or the travel of wire entirely too slow, and second the deposit of zinc must adhere so tightly to the steel that no amount of flexing or deformation will loosen it.

The chemistry of the roasting, leaching and purification processes is exceedingly complex; it has been thoroughly discussed in a voluminous literature and is somewhat aside a metallurgical story. Suffice it to say that the zinc comes into the Cambria plant as a roasted, high grade concentrate. The equipment and methods for preparing the zinc sulphate solution are not unusual to those skilled in the art — it *is* unusual, however, to see such an intricate chemical plant in a steelworks. Every operation in the cyclic process must be under precise control, so that recoveries may be high and the final solution to the cells be of utmost purity. To give some idea of the precision required, germanium — commonly occurring in traces in most zinc — must be removed to limits far below possible detection by analysis; one part in 20 million will seriously reduce the current efficiency.

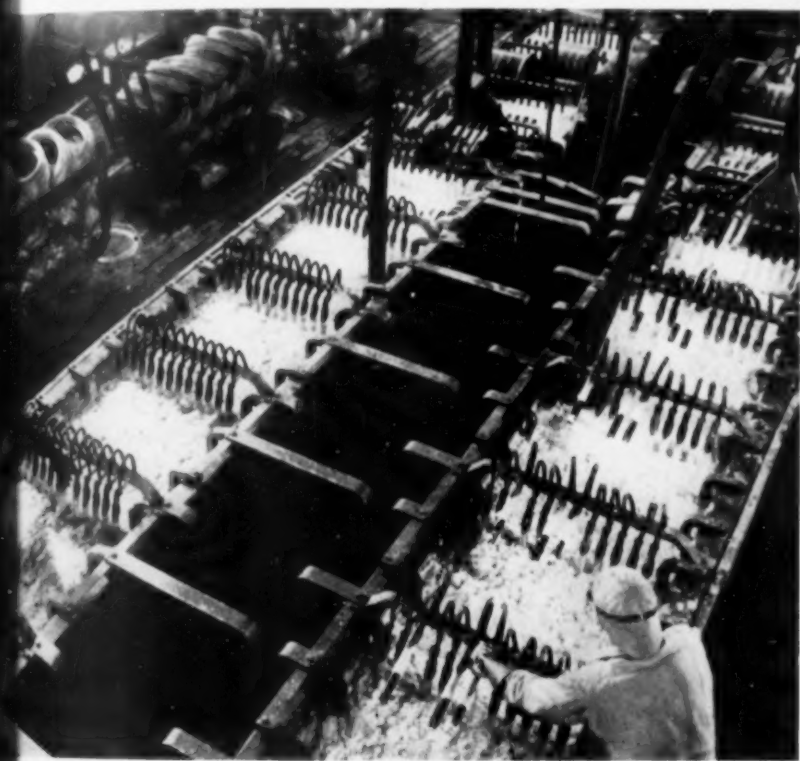
Granted, then, that a practically pure solution of zinc sulphate is prepared, it might be assumed that it would be comparatively simple



**1** *Successive Reels Are Butt Welded Into Continuous Str… Which Pass Through These Tanks of Molten Caustic, … as a Combined Annealer and Cleaner. Surface cond… is of paramount importance for adherence of electroplated z…*

to obtain a perfect coating of pure zinc on steel. This is far from being the case. For the reasons why, Mr. Tainton's words may be quoted:

"One primary difficulty arises from the fact that in depositing zinc from an acid solution we are, in a sense, going contrary to the laws of electrochemistry. When two dissimilar sorts of ions are present in a cathode layer the more electropositive ones (that is, those lower in the electrochemical scale) are discharged first. Consequently, from



2 *Crane-Man's View of Two 110-Ft. Electrolyzing Cells, Each Accommodating 12 Wires. Workmen are adjusting contactors, bearing on submerged wires. Exceedingly high current density is used to deposit a d coating of zinc in the short time it takes wire to pass through these cells*

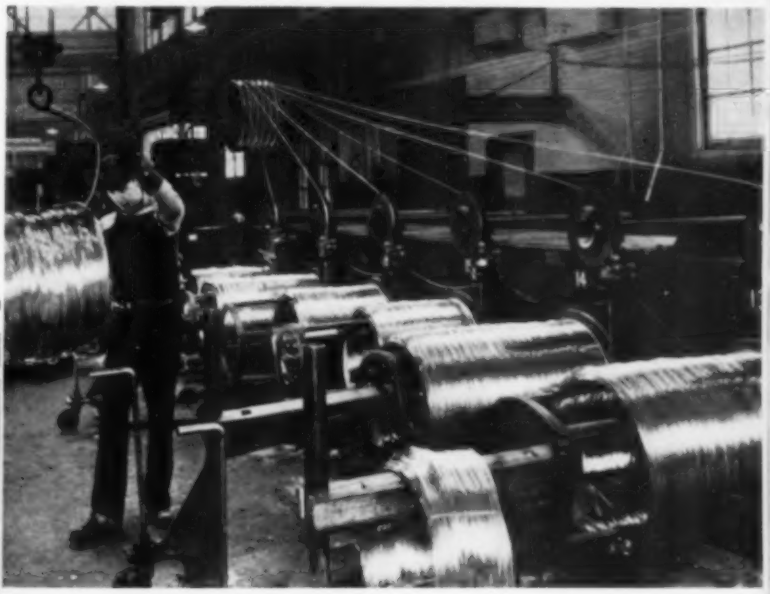
an acid zinc sulphate solution which contains both zinc ions and hydrogen ions we should get at the cathode, theoretically, only hydrogen gas and no zinc. This, in fact, it is only too easy to do! It constitutes the principal reason why electrolytic zinc men grow gray prematurely or lose their hair.

"The deposition of zinc is only possible because of the peculiar phenomenon of 'overvoltage,' the name given to the property that certain materials have of **opposing** the evolution of hydrogen at their surface. Pure zinc has it in a high degree; platinum black hardly at all. It is therefore easy to plate zinc onto a pure zinc surface from an acid solution but impossible to do so onto platinum black. Iron is an intermediate case.

"The hydrogen overvoltage of iron is normally below the potential of zinc on the hydrogen scale; however, it rises with increasing current density, and by sufficiently increasing this factor, zinc may be deposited. However, if the surface of the iron or steel is too rough, spongy, or has certain foreign matter on it, it may be impossible to obtain a zinc deposit at any practicable current density. Hence this factor had to be considered in developing a satisfactory manufacturing process.

"Another difficulty arises in connection with the property that iron has of adsorbing or occluding hydrogen. When hydrogen is evolved at an iron surface, as when steel is pickled in acid, hydrogen gas is occluded by the steel. Everyone is familiar with the fact that hydrogen causes embrittlement. It is not so well known that occluded hydrogen also interferes with the bond between an electrodeposited coating and the steel base.

"Taken in conjunction with the point previously mentioned, it will readily be seen that in attempting to plate zinc onto steel one is skating on rather thin ice. Even if the pickling operation has left no occluded hydrogen in the steel, some may easily be introduced in the plating operation before the deposition of zinc begins, and the subsequent deposit may peel off from the base metal. This can be obviated, however, by taking the right precautions.



3 *After Zinc of Correct Thickness Has Been Deposited, the Wire Is Washed in Tanks Hid by the Workman's Shoulders, and Reeled. He is taking off a bundle of convenient size with safety-first horses and overhead trolley*

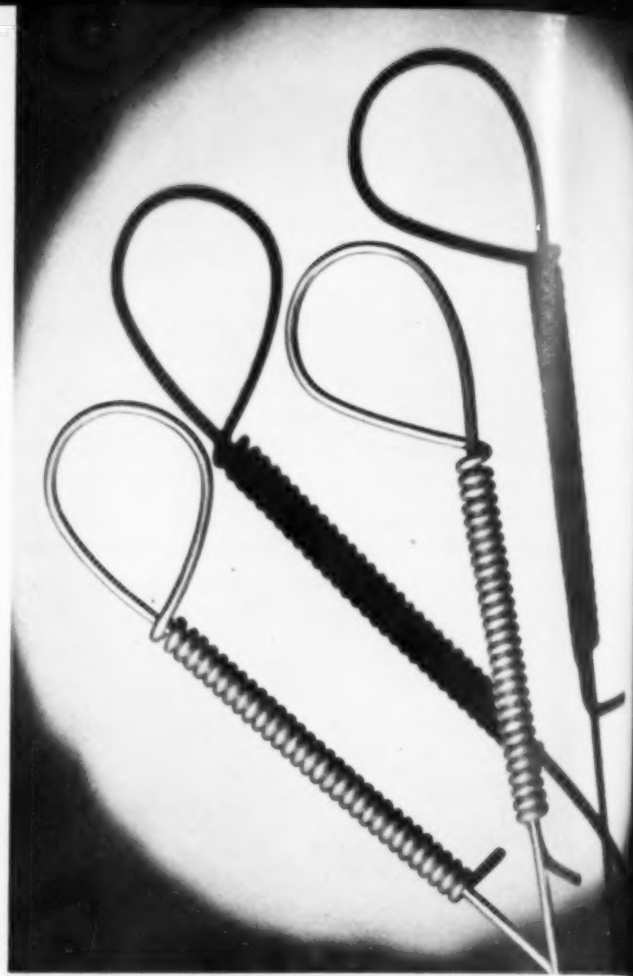
"It is vitally necessary, therefore, that the steel surface be free from all foreign matter such as grease, scale, rust and even spongy metal. It should not contain occluded hydrogen, and none should be introduced before the zinc comes down.

"To meet these conditions completely in the difficult case of steel wire a new cleaning method was developed. This was based on the fact that a strongly electro-negative element such as sodium would attack and combine with any non-metallic substances on the surface, but would not attack the metal itself. The method employed is to make the steel cathode in a fused salt such as sodium hydroxide. The nascent sodium evolved combines with such elements as oxygen, sulphur and phosphorus and produces actually a purer metal at the surface than in the body of the steel itself. All grease or organic matter is eleminated and no hydrogen is occluded."

The actual cleaning devices are somewhat more extensive than might be inferred from the above. The wire, hardened somewhat by the cold drawing operations, passes over a looping device giving necessary slack, and first goes through a pot of molten sodium hydroxide at 1100 to 1200° F.; this is a combined annealer and cleaner wherein the wire is softened to the desired physicals and the die lubricant (soap and lime) is removed. Up and out of this the wire travels into the electrolytic caustic cleaning zone, operating at perhaps 200° F. lower temperature. Current is led into this section by nickel anodes and out through the wire by individual contactors on the bars holding the wire down. This removes scale and other dirt, as described above. Next comes a water tank to cool the wire and wash off most of the caustic carried out, then a second water wash, and finally (if necessary because of spongy surface) an anodic cleaner where the liquid is spent electrolyte, high in sulphuric acid and low in zinc sulphate. In this final tank the wire is made anodic to lead cathodes, the potential is at 6 to 7 volts. The end result is a very thoroughly degasified and bright steel surface.

The wire then threads its way through a wiping box and is immediately submerged under the electrolyte in the main cell. The new unit at the Cambria Plant of Bethlehem Steel Co. at Johnstown, Pa., has two plating cells, each 110 ft. long and normally taking a current of 40,000 amperes at 10 to 10.7 volts. There are 12 wires in each cell traveling at speeds of from 50 to 200 ft. per min., according to the thickness of coating and size of wire.

Electrodeposition of zinc on wire is at current densities from 700 to 2000 amperes per square foot. This is from 20 to 50 times as high as the current density ordinarily employed in plating with soluble zinc anodes and 7 to 20 times that in plants making electrolytic zinc. Since rate of deposition in a properly functioning cell depends on the current density, this permits wire speeds as high as or higher than those of hot-dip galvanizing practice, and a satisfactory and thick deposit at the end.


*Good Electrolytic Coat Withstands Close Bends and Much Abuse Without Cracking or Flaking*

The anodes consist of plates of an alloy of lead and silver which is far more resistant than lead alone. Current is drawn off through contactors riding the wires, as clearly shown in the view on page 527.

Emerging from the electrolytic cell, the zinc deposit has a matte or finely crystalline surface. It immediately is submerged in cold wash water, and then passes through a final wash of clear, hot water. Finally the wire passes through a polisher and is reeled.

At the beginning of this line-up successive reels of bare wire fresh from the draw benches are butt welded so that operations are continuous on endless strands. Power is from the reels at the finishing end, driven individually by variable speed motors. *(Continued on page 544)*

# *Summary of Structural Effects of Alloys on Iron*

*From 1937 Howe Memorial Lecture by Paul D. Merica;*
*Courtesy American Institute of Mining & Metallurgical Engineers.*

| Elements | Per Cent Used in Pearlitic Irons | "Chill" | Effect on Carbides at High Temp. | Effect on Graphite Structure | Effect on Combined Carbon in Pearlite | Effect on Matrix |
|---|---|---|---|---|---|---|
| *Chill-Inducing* | | | | | | |
| Chromium | 0.15 to 1.0 | Increases (Note 1) | Strongly stabilizes | Mildly refines | Increases | Refines pearlite and hardens |
| Vanadium | 0.15 to 0.50 | Increases | Strongly stabilizes | Refines | Increases | Refines pearlite and hardens |
| *Mildly Chill-Inducing* | | | | | | |
| Manganese | 0.30 to 1.25 | Mildly increases | Stabilizes | Mildly refines | Increases | Refines pearlite and hardens |
| Molybdenum | 0.30 to 1.00 | Mildly increases | About neutral | Strongly refines and strengthens | Mildly increases | Refines pearlite and hardens |
| *Mildly Chill-Restraining* | | | | | | |
| Copper | 0.50 to 2.0 | Mildly restrains | About neutral | About neutral | Mildly decreases | Hardens |
| *Chill-Restraining* | | | | | | |
| Carbon | | Strongly restrains | Decreases stability | Coarsens | Strongly decreases | Produces ferrite and softens |
| Silicon | | Strongly restrains | Decreases stability | Coarsens | Strongly decreases | Produces ferrite and softens |
| Aluminum | | Strongly restrains | Decreases stability | Coarsens | Strongly decreases | Produces ferrite and softens |
| Nickel | 0.10 to 3.0 | Restrains (Note 2) | Mildly decreases stability | Mildly refines | Mildly decreases & stabilizes at eutectoid | Refines pearlite and hardens |
| Titanium | 0.05 to 0.10 | Restrains | Decreases stability | Strongly refines (Note 3) | Decreases | Produces ferrite and softens |
| Zirconium | 0.10 to 0.30 | Restrains | | About neutral | | Produces ferrite and softens |

Notes: 1. Chill-inducing effect about balances chill-restraining effect of 1½ parts of silicon or 2½ parts of nickel.
2. Chill-restraining effect about ½ that of silicon.
3. When added in small amounts and particularly when oxygen is also present.

# Correspondence and Foreign Letters

## Workability of Metals

Special letter to Metal Progress
By Prof. Albert Portevin
Central College of Arts and Industry

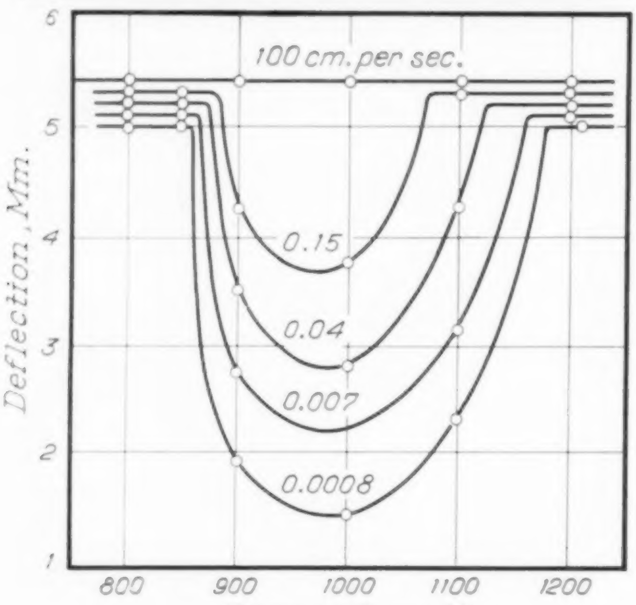
Paris, *France* — Two papers have recently appeared on the subject of workability of metals which give the results of laboratory tests on various alloys. The first, by A. Portevin, E. Pretet and J. de Lacombe, covered steels and copper alloys and was presented to the International Congress of Metallurgy, October 1935. The second, by A. Portevin and P. Bastien, concerned light alloys of aluminum and magnesium, and was read at the last meeting of the British Institute of Metals, held abroad in Paris in October 1936.

The two most important and essential characteristics of workability, or capacity for hot deformation, are the resistance to deformation *R* and the capacity for deformation before rupture *S*. Other useful factors in determining workability are the tendency toward widening in rolling, liability to flaws and other defects occurring during heating and cooling, and sensitivity to the shape of rolls and dies. These characteristics must be determined as functions of temperature, with a definite method and rate of deformation, the latter being most important.

In fact, if the various methods of testing, such as tensile, bend, torsion, and compression are compared, it is found that they classify the various metals as to *resistance* to deformation *R* in about the same manner, even showing a rough quantitative correspondence in spite of the diversity of the adopted characteristics. If a similar numerical correspondence cannot be established for the *capacity* for deformation *S*, at least the various curves representing the variation of *S* as a function of temperature have numerous characteristics in common for various tests carried on at comparable speeds on the same metal. In fact, the zones where fracture occurs at high temperature are similarly located, the minima for one metal are generally found at one temperature, and minima values appear in about the same order for all the metals.

Thus the type of test should be chosen with regard to its sensitivity, accuracy, ease and simplicity of execution. The notched-bar bend test was therefore chosen, on condition that testing should be done without removing the test piece from the furnace in order to avoid temperature errors. (If the temperature is not too high, the impact test may be carried on *outside* the furnace, as long as quick-acting mechanical equipment is used.)

Deformation rate plays a very important part in such testing; it should be carefully chosen and tests should be made at two different rates at least — a low rate (static test) and a high rate (dynamic test). Moreover, it was found experimentally on the metals studied that the resistance to deformation *R* at a given temperature is $R = a\,V^b$, where *V*, the rate, varies within as large an interval as $10^{-3}$ to $10^2$ cm. per sec. Therefore it is sufficient to know the two parameters, *a* characterizing the influence of temperature for a given rate, and *b* the influence of rate for a given temperature. Parameter *a* decreases rapidly with the temperature, *b* is 0.1 to 0.2 for soft steels tested at about 800° C. (1475° F.). The rate greatly affects the capacity for deformation but in a very erratic manner. In some metals (forging brass, for instance) the capacity for deformation *decreases* as the rate increases. In others, the variation is *vice versa;* a typical example is mild electric furnace steel,




*Curves Showing How Deflection at Fracture in Bending Varies With Temperature and Speed of Deformation*

which at low rate of deformation showed a strong tendency toward fracture around 1000° C. (1850° F.) but did not fracture at high rates.

This is shown in the curves for a very soft steel (C 0.08%, Si 0.37%, Mn 0.48%, S 0.01%) giving the deflection for fracture as a function of temperature; there is a maximum tendency toward fracture at about 1000° C., which lessens as the rate increases and finally disappears under impact, at 100 cm. per sec.

ALBERT PORTEVIN

## Metallurgical Education

Special letter to METAL PROGRESS
by Prof. GILBERT E. DOAN
Lehigh University

BETHLEHEM, *Pa.* — I have read with interest and appreciation your editorial on Engineering Education in the March issue of METAL PROGRESS. I can agree with you in your main thesis that the upper classmen in engineering schools should have "a larger and larger amount of time for independent study along a definite but individual line guided by his departmental faculty," ending with nothing more restrictive than a thesis and a comprehensive examination. That is a viewpoint which is coming very slowly to engineering education, but in the end it is certain to prevail.

When you advocate an increasing amount of time for studies in metallurgy, I believe that you run into two serious obstacles. In the first place, if a boy gets the foundations of science and a grounding in the humanities (history, literature, economics, and so on) in four years, with an appetizer in a special field, such as metallurgy, he has done extremely well with his time. The need for the science foundation is obvious. The humanities are necessary too, for without the understanding which comes from them the graduate is unable to see his engineering in its proper background and perspective; unable, as President Roosevelt puts it, to meet the full range of engineering responsibility; unable to understand the place and the problems of the engineer in society. More than this can he scarcely do and do well in four years, and four years is long enough for the great majority of boys.

The second obstacle is the fact that less than half of the graduates in a special field of engineering actually follow it as a life work. They get into sales, where the foundations are more valuable than the special knowledge. Or they get into mechanical or civil engineering instead of metallurgy, or they get out of engineering entirely — not because there are not excellent opportunities there, but because of family connections in another field, or because of local industries not of a metallurgical nature, or through friends and other chance factors. When they graduate, they go where the best offer is made, where the best future looms — whether it is in the chosen specialty or not.

The time for extensive specialization is *after* the foundation is laid, and after the boy finds what field he will finally get into as a life work. In the industry, after he joins it, he will be assigned to a special field. To it he should bring a sound fundamental scientific knowledge and rapidly he will learn the special techniques and problems involved. In a few cases the graduate may want to come back to college for graduate work, but usually the best place to learn technology is in industry. Specialization is worth any man's time, but premature specialization is a speculative risk and for the majority of boys a bad investment.

The "individual line" that you mention, which an upper classman can choose toward the end of his course, really is engineering, or at best metallurgical engineering. But the structure of an engineering career cannot rise very high if the foundations are weak and sketchy.

GILBERT E. DOAN

## Improved Toughness After Short, Low Tempering

Special letter to METAL PROGRESS
by B. SHEININ
Metallurgical Engineer, Elektrostal Works

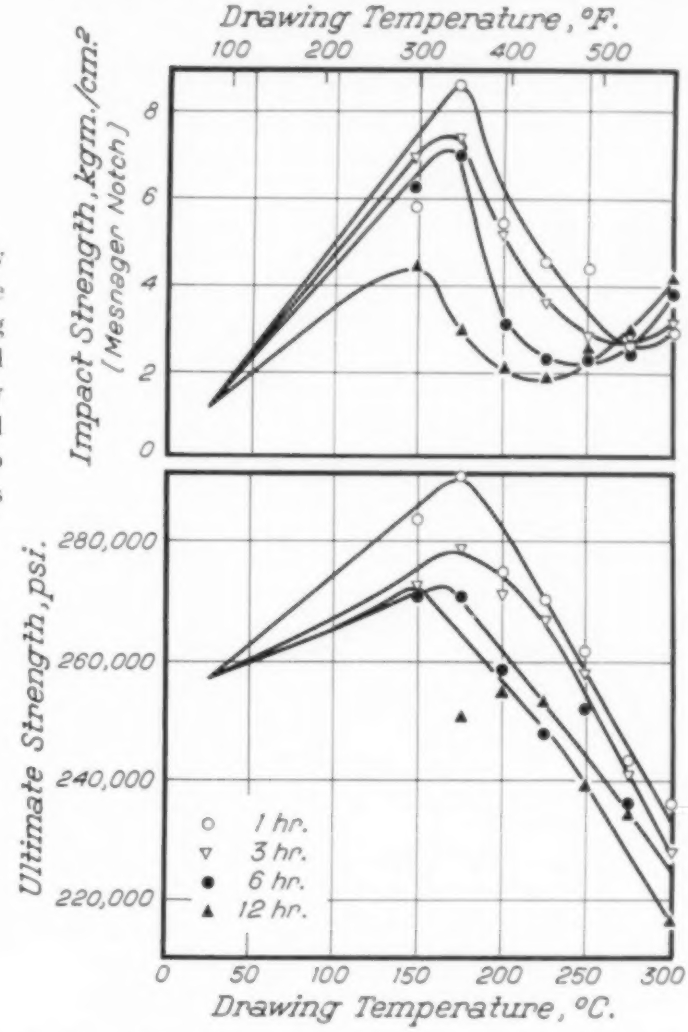
Moscow, *U.S.S.R.* — A. A. Chabachpashev and the present writer published some work in the Russian language in 1934 showing how to secure combinations of high strength and toughness in the engineering alloy steels by quenching from a high temperature followed by a low draw (350 to 450° F.). This seems to be a critical range, because most quenched steels are deficient in toughness if they are tempered between 600 and 750° F.

Prof. George W. Akimow verified the above statements and, in a letter to METAL PROGRESS last November, ventured the opinion that the higher toughness after higher quench and lower draw was due to a more uniform solution of carbide, or a solution of impurities otherwise concentrated at the grain boundaries. Variation in amount of residual austenite was eliminated as a cause, since his magnetic tests showed the amount of gamma phase to be the same in steels after higher and higher quenching, drawn back to the same low temperature.

Some work carried out by the writer in the research laboratory of the Elektrostal plant indicates more clearly the nature of the internal changes during the treatments noted. We worked on a steel containing 0.40% carbon and 1.0% chromium, rolled to 1-in. round rods. Tensile test bars of 10-mm. diameter and 50-mm. gage length (0.394x1.968 in.) and 10x10x60-mm. impact test bars with 2-mm. Mesnager notch were prepared. The stock had previously been normalized from 1600° F. and annealed at 1200° F. Test bars were oil quenched from 860° C. (1580° F.) and samples tempered from 150, 175, 200, 225, 275 and 300° C. respectively (300 to 575° F.). For each tempering temperature, soaking times of 1, 3, 6 and 12 hr. were used.

Ultimate strength and impact strength vs. tempering temperature, plotted in the figure, show the following relationships:

1. Increase of soaking time at tempering temperature decreases the maximum impact toughness and displaces this maximum value toward lower temperatures.




*A Short, Low Temperature Tempering Improves Strength and Toughness of S.A.E. Steels Quenched From as High a Temperature as Possible Without Causing Grain Growth*

2. The same is true of the temperature for minimum impact toughness.

3. The same is true of the temperature for maximum ultimate strength.

4. The maximums of impact toughness and ultimate strength coincide accurately for all soaking periods.

We believe that these regularities allow us to define a succession of processes as taking place during tempering of steel and influencing its mechanical properties in the manner described in what follows:

First stage (during reheating from room temperature to 300° F., approximately): Precipitation of submicroscopic particles of carbide from supersaturated $\alpha$ solid solution (martensite) resulting in an increase of toughness in consequence of relief *(Continued on page 560)*

## Aluminum Telephone Wire

Special letter to Metal Progress
by Federico Giolitti
Consulting Metallurgical Engineer

Turin, *Italy* — A great effort has been made in Italy, in the past few years, to replace copper wherever possible with aluminum alloys. The reason is that copper is produced only in very small quantities in Italy, while huge deposits of bauxite and leucite exist in many parts of this country, and our production of aluminum from domestic ore is increasing very rapidly.

In some of my preceding letters to Metal Progress a few data have been quoted concerning the results of these efforts in certain particular fields — especially for power transmission lines. Similar excellent results have also been obtained in the use of aluminum wires for telephone lines. As is well known, the study of this problem has led to different solutions in different countries. A few data concerning the practice adopted in Italy may, perhaps, show that some details do not correspond completely with those adopted elsewhere.

The aluminum alloy definitely adopted for our telephone lines, to the exclusion of all other alloys known at present, and of all compound types of wire, is the alloy known as "aldrei," a ternary alloy of aluminum, silicon and magnesium. It has some peculiar properties of special importance for this particular application.

The adjoining table shows the more typical properties of heat treated aldrei, compared with those of other materials generally used for telephone wire. The figures refer to 8 to 12-gage wire sizes.

When aldrei is manufactured and treated with the necessary care it shows remarkable resistance to the chemical action of atmospheric agents. Very extensive experiments show that the durability of aldrei wire is fully satisfactory in all exposures normally met in practice when its Mylius reaction number (see Metal Progress, February 1937, page 175) is within the following limits, easily obtained under normal manufacturing conditions:

1. For wire drawn from extruded bars, 1.5 to 2.5.

2. For wire drawn from rolled bars, 2 to 3.

When the corrosion numbers do not exceed the limits above quoted, the combined corrosion fatigue resistance is also very high.

*Physical Properties of 8 to 12 Gage Telephone Wire*

| Properties | Aldrei | Aluminum 99.5% | Copper | Normal Cu-Sn Alloy | Galvanized Iron |
|---|---|---|---|---|---|
| Tensile strength, psi. | 42,500 to 51,000 | 23,500 to 26,000 | 57,000 | 85,000 | 65,000 to 70,000 |
| Elongation in 2in., % | 5 to 9 | 2.4 | 1.3 | 1 to 2 | 5 |
| Yield point, psi. | 38,000 to 44,000 | 21,000 to 24,000 | 50,000 to 57,000 | 50,000 | 42,000 to 50,000 |
| Elastic limit, psi. | 27,000 to 31,000 | 11,000 to 14,000 | 28,000 to 35,000 | — | — |
| Modulus of elasticity, psi. | 9,250,000 | 8,500,000 | 15,500,000 | 15,500,000 | 27,000,000 |
| Conductivity at 20°C., m./Ω/mm.² | 30 to 32.5 | 34.5 to 35.5 | 52 | 52 | 7 |
| Resistivity at 20°C., Ω/mm.²/m. | 0.0333 to 0.0308 | 0.0290 to 0.0282 | 0.0178 to 0.0175 | 0.0190 to 0.0195 | 0.143 |
| Thermal coefficient of resistivity | 0.0036 | 0.0041 | 0.004 | 0.004 | 0.005 |
| Number of torsions | 8 to 12 | 12 to 16 | 12 | 10 to 16 | 15 to 20 |
| Number of bends (on 10mm. radius) | 6 to 10 | 10 to 14 | 4 | 6 | |
| Specific gravity | 2.7 | 2.7 | 8.9 | 8.9 | 7.8 |
| Coefficient of thermal expansion | 0.000023 | 0.000023 | 0.000017 | 0.000018 | 0.000012 |

Except for the joints, the installation of aldrei wire in telephone lines does not require unusual precautions. Special devices must be used where adjoining surfaces are strongly pressed together, in order to avoid the formation of an insulating oxide film. Very simple and efficient types of joints have been obtained for this purpose.

While in different countries — for instance, in Switzerland — single wires are used practically in all circumstances, in Italy twisted triple or multiple strands are always used for lines running near the seashore, and usually

where feeble but constant winds blow in a direction approximately normal to the line, causing continuous vibrations. Under these last conditions, the results obtained with the twisted triple strands have been excellent, even where stronger single-wire lines of the same net section had previously given serious trouble.

On the other hand, single-wire lines have given excellent results in mountainous regions, even those having a heavy snowfall, very low temperature, and strong, but not continuous, winds.

These same conclusions have been reached in France, where in many instances the troubles given by a single-wire line of aluminum alloy disappeared completely when the single wire was replaced by a triple strand of the same alloy, having the same cross section.

The normal safety margin for tensile stresses long since adopted for copper lines has been maintained for aldrei lines. In Italy the working limit is one-third the tensile strength for a temperature of zero Fahr. and a wind velocity of 80 miles per hr. In Switzerland, the limit is one-half the tensile strength for 0.5 lb. of snow per ft. and one-sixth the tensile strength at zero Fahr., with no overload.

FEDERICO GIOLITTI

## High Chromium Irons and Steels

Special letter to METAL PROGRESS
by Prof. EDUARD MAURER
Freiberg School of Mines

FREIBERG, *Germany* — Commercial expansion of stainless steels in Germany cannot be compared to that in the United States, not only because of the expense and scarcity of nickel and chromium, but because the patent situation is entirely different. Interest in 18-8 first began to be evidenced in America about 1928, much later than in Germany, for Krupp's two so-called "Pasel" patents ran out at the end of 1935. However, it will not be possible to manufacture 18-8 without infringement in Germany until May of this year, since another patent, also belonging to Krupp, claims steels with silicon above 0.2%, and it is not actually possible to make these steels with less silicon than that. Krupp has issued no licenses in Germany for 18-8; others can manufacture only the nickel-free chromium steels. The Böhler firm avoids this by holding rights to produce in Austria, and makes its 18-8 at the plant in Kapfenberg.

To what extent the use of stainless steel in Germany will now spread cannot be foretold, since the "weldability" of 18-8 is protected by two re-issued Krupp patents. The first covers the carbon content (less than 0.07%), and the second concerns the use of titanium or vanadium or both for the purpose of fixing carbon as insoluble carbides. Whether these patents will hold is a question, for Böhler Bros. & Co. obtained a prior patent on the use of tantalum, wherein the function of stable carbides was clearly described. Other patents have been issued covering columbium; I understand that the Böhler firm believes that its patent and licensees will not be affected because all ferrotantalum contains more or less columbium, and even analytical separation was impossible until recently.

As to the relative advantages of these elements, I quote a communication from Dr. F. Rapatz of the Böhler firm:

"I do not believe I exaggerate in naming the following advantages of tantalum over titanium additions:

"1. Titanium steels are troublesome to work because of their tendency to form a thin scale, likely to be troublesome in the fabrication of sheet.

"2. General corrosion is increased somewhat by the addition of titanium and tantalum, and the steel impaired in this respect. This is particularly noticeable after cold working. In our experience tantalum makes the steel less sensitive than titanium.

"3. In welding, particularly electric welding, titanium burns out of the weld metal more easily than tantalum. The welding bead then represents a steel no longer stable against dissociation (weld decay). This is especially troublesome if a second layer is welded over an already existing bead, whereupon susceptible metal underlies the first welded bead. Tantalum is more readily held in the weld metal and this detrimental influence is therefore much reduced.

"A disadvantage of tantalum is, of course, that it is more expensive than titanium. I believe, however, that in view of the general high price of the products, especially sheet, this disadvantage is of minor importance."

It is readily seen, therefore, that most of the German makers of special steels are more than usually interested in those varieties of stainless that contain no nickel. One result is that the so-called "Sicromal" steels of the

"Remanit" Produced by Deutschen Edelstahlwerke

| Mark | C | Mn | Si | Cr | Ni | Mo | Other Elements |
|---|---|---|---|---|---|---|---|
| Remanit 1510 | 0.10 | 0.40 | <0.45 | 15.0 | 0.50 | — | — |
| " 1520 | 0.20 | 0.50 | 0.65 | 15.0 | 0.50 | — | — |
| " 1530 | 0.30 | 0.40 | <0.45 | 15.0 | 0.50 | — | — |
| " 1530 F | 0.30 | 0.50 | 1.40 | 15.0 | 0.50 | — | — |
| " 1540 | 0.40 | 0.40 | <0.45 | 15.0 | — | 0.25 | — |
| " 1610 | 0.10 | 0.40 | <0.45 | 16.0 | 2.00 | — | — |
| " 1620 | 0.20 | 0.40 | <0.45 | 16.0 | 2.00 | — | — |
| " 1710 | 0.10 | 0.40 | <0.45 | 17.0 | 0.50 | 1.80 | — |
| " 1710 A | 0.10 | 0.40 | <0.45 | 17.0 | 0.50 | 0.40 | 0.20 S |
| " 1710 S | 0.10 | 0.40 | <0.45 | 17.0 | 0.50 | 1.80 | 0.70 Ti |
| " 1740 | 0.40 | 0.40 | <0.45 | 17.0 | 0.50 | 1.50 | — |
| " 1790 | 0.90 | 0.40 | <0.45 | 17.0 | — | 1.00 | |
| " 1790 C | 0.90 | 0.40 | <0.45 | 17.0 | — | 0.50 | 1.50 Co, 0.30 V |
| " 1800 M | 0.08 | 9.00 | <0.45 | 18.0 | 1.50 | — | |
| " 1880 S | 0.09 | 0.40 | <0.45 | 18.0 | 8.00 | — | 1.50 Ta |
| " 1880 SS | 0.09 | 0.40 | <0.45 | 18.0 | 8.00 | 2.00 | 1.00 Ta |
| " 2810 | 0.10 | 0.40 | <0.45 | 28.0 | 1.50 | 2.00 | 0.70 Co |
| " 0327 | 0.10 | 1.25 | 3.00 | — | 27.0 | 2.00 | 2.00 Cu |

Deutschen Rohrenwerke, Düsseldorf, were developed as high chromium-iron alloys with additions of aluminum or aluminum and silicon. These steels were not used as rust resisting steels (true stainless) but primarily as heat resisting steels and later as acid resisting steels. They may not be substituted in all cases for the acid resisting 18-8 with 2% molybdenum — grain growth during welding is not entirely to blame, for both types of steel are markedly subject to this phenomenon.

Improvement in the weldability of martensitic steels and ferritic chromium-iron alloys has been widely sought. William Oertel of the Deutschen Edelstahlwerke, Krefeld, has patented a non-austenitic chromium-molybdenum steel with 18% Cr and 1.5 to 2% Mo. One valuable characteristic of the Cr-Mo steels proved to be a great increase in resistance to many chemicals over the normal chromium steel. The low carbon alloy of this group is frequently on a par with 18-8 as to its chemical stability, and even excels it for many requirements. It is also considerably cheaper, and therefore the chromium-molybdenum steels find their major application in the construction of chemical apparatus. Architectural and machine construction utilizes them when corrosion requirements are too high for the normal chromium steel. Steels of the 1700 series in the attached tabulation come under the Oertel patent. An idea of the other stainless steels produced by this firm and marketed under the trade name "Remanit" is given in the tabulation at the left.

Edelstahlwerke Rochling-Buderus A. G., Wetzlar, has developed a new stainless chromium-manganese steel by the name of "Roneusil" with an approximate composition of 16% Mn, 7 to 9% Cr, and 1% Mo. The *Frankfurter Zeitung* described the steel as follows:

"It is an alloy steel, which, in contrast to the stainless chromium-nickel steel, contains a large percentage of manganese but no nickel. This is not its only distinguishing characteristic, however, for this steel, which is completely resistant to acids found in domestic use and the food industries, also has a very pleasing appearance. It has a high light reflectivity so that it somewhat resembles nickel silver. The fabrication properties of this steel are so good that it is particularly suitable for the manufacture of household articles such as cutlery, kitchen utensils of all types, and dishes, as well as for ornamental decoration such as vignettes and frames."

EDUARD MAURER

## The "Incubation" of Alloys

SENDAI, *Japan* — When duralumin, and many other alloys, are given a solution heat treatment and quenched, the subsequent age hardening may not begin immediately, but in many cases one hour or more afterward. This interval is known as the "incubation period." Kanzi Tamaru and the writer have investigated this action in a 1.94% beryllium copper (Cu-Be being the only copper alloy of many of its age hardenable alloys that shows the phenomenon) and in a specially pure duralumin. We studied the effect of size of specimen, temperature and time of annealing, and temperature of aging on the way the hardness, electrical resistance and density of the alloys vary with aging time.

According to the theory of hardening proposed in 1930 by the present writer and S. Kokubo, age hardening is not caused by the precipitation of fine *(Continued on page 546)*

# Personals

**Alfred E. Gibson**, formerly executive vice-president, has been elected president of The Wellman Engineering Co., Cleveland.

**Claude L. Roth** has formed a partnership for the general practice of law in Philadelphia under the name of Moffett & Roth.

**Robert S. Williams**, long professor of physical metallurgy at Massachusetts Institute of Metallurgy, has been made director of the newly created Department of Metallurgy at that institution.

**Robert W. Van Wagner** has been transferred from the Ansonia Branch, American Brass Co., to the Waterbury Branch, in the Copper Alloy Research Laboratory, Physical Testing Dept.

**R. J. Wysor** has been elevated from General Manager to President of Republic Steel Corp.

**Robert W. Crosby** has been made district manager of the new office of Minneapolis-Honeywell Regulator Co. in Portland, Me.

**Reynold F. Svensk**, formerly with the Hartford Electric Steel Corp., has been made New England sales representative for the Atlas Steel Casting Co., Buffalo.

**Rolf G. Sartorius** has accepted a position as metallurgist with the National Lock Washer Co., Newark, N.J. He was previously with the Crucible Steel Co. of America.

**W. M. Harvey** has been appointed sales engineer for the Bristol Co. covering northern and eastern Indiana and the South Chicago area.

**Richard C. Pranik**, formerly metallurgist at Indiana Motorcycle Co., Springfield, Mass., now holds the position of metallurgist in the Research Department of the American Screw Co., Providence.

**C. Woodie Patterson** is now connected with the Engineering Department of Cadillac Motor Co.

**G. Kingman Crosby** has joined the International Nickel Co. at Huntington, West Va.

**George B. Brimhall** has accepted a post as apprentice engineer for Pan American Airways.

**John F. Pollack** has resigned from Page Steel and Wire Co. to join Jones and Laughlin Steel Corp. at Aliquippa.

**Thomas J. Wood** has terminated his position as research metallurgist with the Bayonne Laboratory of the International Nickel Co., Inc., to become associated with the Robins Conveying Belt Co., Passaic, N.J.

★ Hair breadth accuracy, equal to the work of first grade machining practice, is one of the money-saving features of Union Cold Drawn Steels. The need of machining is eliminated wherever the bright finish of these steels can be retained in the completed parts. The bars pass smoothly through feed mechanisms and collets of automatic screw machines. Hourly output is increased.

Union Cold Drawn Steels also have the advantage of extra machinability which assures the maximum speed in production.

**UNION DRAWN STEEL CO.**

MASSILLON, OHIO

A SUBSIDIARY OF REPUBLIC STEEL REPUBLIC STEEL CORP

# *Cold Drawn* Steels

(Continued from page 528) As the finished wire accumulates, it is taken off the reels in bundles of convenient weight.

The inquiring reporter brought up the point of hydrogen embrittlement. Almost everyone who has expressed an opinion about electrogalvanizing of high carbon wire has mentioned this difficulty. Numerical data showing number of bends, torsion number and tensile tests of bare stock, Bethanized wire and conventional hot galvanized wire were not easily comparable owing to the annealing effects of the cleaning operation in the one case and the hot zinc in the other. Perhaps a better proof is the fact that any hydrogen in or on the bare wire would immediately show up in a poorly adherent coating, and second that customers using this as "manufacturer's wire" are not complaining of any difficulty in their fabrications. In one recorded instance, 16-gage telephone wire (0.062 in. diameter) was cold drawn to a 0.003-in. filament without breakage of wire or destruction of the coating. These practical facts may be as convincing as a tabulation of laboratory tests.

The combination of tenacious bond, pure zinc and smooth, bright appearance is very appealing. Wire with any desired weight of zinc coating can be fabricated without injury to that coating. The result is that joints in fencing or close wound splices have a continuous coating of zinc which has not been reduced in thickness by any flaking or powdering.

Coatings have been applied commercially, as desired, in a full range from the thinnest to others three or more times the thickness of the heaviest made by hot galvanizing. This new variety of coating is also built up in an electrolyte with sufficient current density and throwing power so it is uniform in thickness. Inasmuch as the zinc is carried onto the surface of the wire by the electric current, the amount of zinc deposited can be definitely and accurately controlled by controlling the amperage on the cell and the speed of the wire through the cells.

As a result of this new process, the Bethlehem organization is convinced that it can now provide fence and barb wire (and other products) made from wire which carries a heavier coating of zinc than has heretofore been commercially possible, and with uniformly better protection against possible damage by subsequent fabrication, than has been heretofore practically attainable. Furthermore, the uniformity of this coating and its purity should result in added years of service.

## Incubation

*(Cont. from page 536)* particles from a supersaturated solid solution, but to a process taking place *before* such precipitation begins. We believe that a local concentration of the dissolved substance in the vicinity of grain boundary is the primary cause of age hardening. Precipitation itself is primarily a softening action, since solid solutions are generally harder than the precipitated mixture of constituents. However, at the same time the precipitation of fine particles has the same effect as grain refining, and this hardens the alloy. In the most cases, this differential effect of softening and hardening amounts to a softening, and therefore precipitation of surplus constituent in discrete particles is generally accompanied by softening. In some other cases, a local concentration of dissolved atoms in the lattice of the mother metal distorts the lattice enough to cause quite useful hardening. The data observed in the present investigation are satisfactorily explained as the combined effect of hardening and softening above referred to.

The copper-beryllium and duralumin alloys quenched from a high temperature are in a state of supersaturated solid solution and hence are in an unstable condition. The distribution of the dissolved atoms within the alloy is not uniform; that is, these atoms are more closely packed near the grain boundary than in its interior, as they move toward the grain boundary even during the rapid cooling in quenching. In the first stage of aging, the dissolved atoms in the vicinity of the grain boundaries slowly move toward the boundary and there they are precipitated as fine particles.

The dissolved atoms in the grain interior, that is, the greater part of the dissolved atoms, also move slowly toward the boundary, greatly distorting the lattice, and they cause a greater amount of hardening in some latter period of aging. If these atoms begin to precipitate, softening commences to be observable. These conclusions have actually been confirmed by the time-hardness curves plotted in our investigation, and published in the reference cited.

The observed changes of electric resistance during aging can also be explained in a similar way. Distortion of the lattice increases the electric resistance and the precipitation of the

dissolved substance causes a decrease in its resistance. Thus, the observed initial increase of resistance and its subsequent small decrease are due respectively to the distortion of the lattice by dissolved atoms present in the vicinity of the grain boundary and to their precipitation. We observed, as time progressed, a second slight increase just before a large decrease of resistance; these two changes are due to the differential effect of hardening and softening caused by the slow movement of dissolved atoms in the interior of grains toward their boundary and by their precipitation respectively.

The density of the alloys is decreased by quenching. Precipitation therefore results in an increase of it, but the lattice distortion causes a decrease of density. The initial decrease of density observed in the first stages of aging is due to the lattice distortion caused by the dissolved atoms present near the grain boundary, and the following increase in density is attributed to the precipitation of these atoms. In the density-time curves these early changes are followed by a subsequent decrease and increase of density which are due to the more numerous atoms in the grain interior.

The effect of aging temperature is to accelerate both the movement of the dissolved atoms and their precipitation. In this way, the four stages of aging effect in the case of hardness, electric resistance and density can completely be explained.

As we have seen, a prolongation of the time at solution-treatment temperature renders the phenomenon of incubation more conspicuous, because the solubility of beryllium in copper, or of copper and $Mg_2Si$ in aluminum, rapidly increases with the rise of temperature, and hence the dissolution of the metal or the compound is much easier at high temperatures and is greater after a prolonged annealing. A greater quantity of these atoms are held in the dissolved condition after quenching, and the metal and compound are thus in a less stable condition.

The curious fact that the thinner specimens are more susceptible to the age hardening effects than the thicker ones is due to the effect of cold working on the solid solubility. The thinner specimen has undergone a severer cold working than the thicker specimen; hence crystal grains are finer in the former specimen than in the latter; this causes a difference in the solubility at high temperature, or in precipitation velocity and hence in susceptibility to age hardening.

KOTARO HONDA

# *Help Yourself* *to this* HELPFUL LITERATURE

## Copper Bulletin

A new clearing house for news of developments in brass, bronze and copper, the "Copper Alloy Bulletin," issued by the Bridgeport Brass Co., made its appearance with the March issue. It is edited for the technical and engineering audience. Bulletin Da-163.

## Riveting Aluminum

The riveting of aluminum and its alloys is treated from all angles in a comprehensive little booklet by the Aluminum Co. of America. Materials, types, riveting practice for various applications, and properties of the riveted joint are covered. Bulletin Da-54.

## Pot Furnaces

Pot furnaces for hardening, tempering and forging are described by Surface Combustion Corp. by means of illustrations and complete data concerning an existing installation. The folder also tells about Surface Combustion air heaters. Bulletin Da-51.

## Toolmakers' Microscope

Only recently have optical methods of measuring and testing been introduced in the workshop. These methods — particularly adapted to measuring small and intricate parts — and the equipment used are fully described in a booklet by E. Leitz, Inc. Bulletin Da-47.

## Insulation Service

"Barriers to industrial waste" is what Johns-Manville calls insulating materials. A small 64-page booklet catalogs their complete line, which contains a product for every temperature. Bulletin Da-100.

## Welding Pipe Lines

An improved welding method used in the construction of over 5000 miles of cross-country pipe lines is discussed in a 32-page illustrated booklet published by The Linde Air Products Co. Bulletin Da-63.

## Optical Pyro

No correction charts, accessories, nor upkeep are required with the Pyro optical pyrometer, which is a totally self-contained direct-reading precision instrument made by Pyrometer Instrument Co., and described in Bulletin Ay-37.

## Light Case

Severe breakdown tests were run by A. F. Holden Co. to study the characteristics of Holden Light Case in relation to case penetration and the total change of chemistry of the bath. They are described, and a chart showing results is reproduced, in a folder ready for distribution. Bulletin Dy-55.

## Turbo-Compressors

Spencer Turbine Co. has turbo-compressors in all sizes and types for oil and gas-fired furnaces, ovens and foundry cupolas. Special types for special purposes such as gas-tight and corrosion resisting applications are also described in Bulletin Da-70.

## Tool Steel Selector

A wall chart, 30 x 20 in., to be used as a means for selecting the proper type of tool steel is offered by Carpenter Steel Co. to tool steel users in the U.S.A. only. Bulletin Jz-62.

## Hydraulic Tester

Of interest to all engineers recommending or purchasing universal testing machines is a book by Riehle Division of American Machine and Metals, Inc., on the development of the precision hydraulic testing machine. Bulletin Ba-157.

## New Joining Process

Metal parts are joined cheaply, neatly and strongly by Electric Furnace Co.'s new, inexpensive non-oxidizing furnace atmosphere and their new, continuous brazing, coppering and soldering furnaces. Full details are given in Bulletin Ar-30.

## Spectrum Analysis

The elements of both qualitative and quantitative spectrum analysis are contained in a handy booklet by Carl Zeiss, Inc. A price list covering all equipment is included. Bulletin Da-28.

## Meehanite

A compact but complete specification chart gives the recommended grades of Meehanite metal for various service requirements. Complete physical properties and applications are included. Bulletin Da-165.

## Alloy Castings

Michiana Products Corp. has published a new book describing Michiana corrosion resistant and stainless steel alloys. Generously illustrated, it suggests many savings for the use of these alloys. Bulletin Oy-81.

## Molybdenum

Climax Molybdenum Co. presents their annual book giving new developments in molybdenum, particularly as an alloy with iron and steel. The engineering data presented are made clear by many tables and illustrations. Bulletin Dc-4.

## Liquitol

The use of Liquitol for controlled cooling of iron and steel castings and ingots is fully described in a bulletin by Alpha-Lux Co., Inc. Bulletin Ma-120.

## Laboratory Service

A new edition of "The Metal Analyst" tells about an organization established by Adolph I. Buehler specializing in the installation of metallurgical laboratories. The complete line of laboratory equipment marketed by Buehler is also catalogued. Bulletin Dy-135.

## Forging Steel

A folder on J & L "correct balance" forging steel shows how consistent profits can be obtained in the forge shop with better quality parts and greater customer satisfaction. Jones & Laughlin Steel Corp. Bulletin Ea-53.

## Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

## Stainless Data Book

All users of stainless and heat resisting alloys should find invaluable the information contained in a booklet published by Maurath, Inc. giving complete analyses of the alloys produced by the different manufacturers, along with the proper electrodes for welding each of them. Bulletin Jy-125.

## Stress-Strain Recorder

The many applications of the Baldwin-Southwark stress-strain recorder, its unique advantages, and the many ways it can give unusual service will be extremely interesting to all who have to do with testing methods and equipment. Bulletin Ba-67.

## Nickel-Copper Steels

Exceptional resistance to corrosion and abrasion, increased tensile strength, and higher ductility are the qualities claimed for Youngstown Sheet & Tube Co.'s new series of Yoloy steels. A summary of properties and notes on their characteristics are contained in Bulletin Ox-93.

## Centrifugal Castings

Centrifugal casting of stainless, heat and corrosion resisting alloys eliminates impurities and cooling strains and permits thinner and more uniform walls than any other method. This is explained in a bulletin by Michigan Steel Casting Co. Bulletin Nx-84.

## Photo-Electric Cells

If you are not familiar with the wide field of applications for photo-electric cells and apparatus, send for this very interesting and complete booklet by Pfaltz & Bauer, Inc. covering the original apparatus developed by Dr. Bruno Lange. Bulletin Ca-142.

## Pyrometers

What pyrometers can do for you is shown in an excellently printed book, illustrated in color, covering the complete line of pyrometers of the millivoltmeter type made by Brown Instrument Co. Bulletin Ea-3.

## Testing Machines

An extremely handsome, spiral-bound, segregated catalog tells all about the various hydraulic and screw power testing machines made by Tinius Olsen Testing Machine Co. Bulletin Oy-147.

## Diamond Wheels

A striking presentation is made by the Carborundum Co. in a 52-page booklet on diamond wheels. Detailed technical information is contained and a price list attached. Bulletin Ca-57.

## Port Valves

Diagrams and descriptive matter show the operation of adjustable port valves made by North American Mfg. Co. that are particularly suitable for mediums whose rate of flow is not constant. Bulletin Oy-138.

## Newer Tool Steels

Vulcan Crucible Steel Co. has a complete and attractive catalog listing their full line of tool steels including many special types to meet the modern trends in industry. Bulletin Jy-127.

## Nickel Silver

Riverside Metal Co. has just published a beautiful booklet on nickel silver. If you want the latest information on this subject, presented in an attractive, interesting manner, write for Bulletin Aa-156.

## Micromax Model

A novel publication by Leeds & Northrup Co. has the effect of almost putting a half-size model of the Silver Anniversary Micromax recorder in your hands. Cut to the actual shape of the recorder, it can be opened out and the whole mechanism swung into place. Bulletin Ca-46.

## Resistance Wire

A complete catalog of the various types of electric resistance wires made by Hoskins Mfg. Co. has been issued. Complete numerical data are included on all types, along with some fundamental facts about heating units. A handy, small size 48-page booklet. Bulletin Jy-24.

## Cleaning Rooms

A catalog of designs for blast cleaning rooms incorporating many labor and time saving improvements making the blast room an unequalled mechanical device for low cost cleaning is published by Pangborn Corporation. Bulletin Ca-68.

## Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

## Galvanizing

An informative, historical, simple digest of galvanizing forms a guide to longer life for iron and steel products. This handsome, handy, 24-page book beautifully printed in color is distributed by American Hot Dip Galvanizers Association, Inc. Bulletin Ea-167.

## Air Heaters

Diagrams, illustrations and detailed text in a folder by General Combustion Corp. give a very clear conception of the construction and applications of General air heaters. Bulletin Ea-166.

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## Refractory Blocks

Light-weight, low heat storage insulating refractory blocks known as "Insulblox" for reducing heat storage and radiation losses at operating temperatures up to 2200° F. are described in a folder by Quigley Co. Bulletin Ea-139.

## Ni-Cr Castings

Compositions, properties, and uses of the high nickel-chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

## Rockwell Tester

A revised and completely up-to-date catalog on the well-known Rockwell hardness tester is well illustrated and contains 24 pages. Published by Wilson Mechanical Instrument Co., Inc. Bulletin Ca-22.

## Salt Bath

"Heating from the inside out" is what makes the Ajax-Hultgren salt bath furnace practical. Ajax Electric Co. explains this new operating principle in an interesting folder. Bulletin Oy-43.

## Dust Collector

How the Schneible multi-wash dust and fume collector operates and what it does are clearly shown in a catalog giving details on existing installations. Published by Claude B. Schneible Co. Bulletin Ca-161.

## Ovens for Finishing

Despatch Oven Co. has two new bulletins featuring ovens for various finishing processes on such things as steel barrels, bed springs, cabinets, stoves and steel doors. Bulletin Oy-123.

## Inert Gas

The rapid development in the use of inert gases in industry during recent years makes a folder of Roots-Connersville Blower Corp. particularly timely. It describes the Harrison inert gas producer — a fairly new but well-proven piece of equipment. Bulletin Ca-131.

## Tool Room Furnace

A new type of lining and one-valve control are two of the features of the American Gas Furnace Co.'s new tool room oven furnace that would make it economical to replace many older furnaces now in operation. Fully described in Bulletin Ox-11.

## Tocco Process

This amazing new and extremely accurate method of heat treating is described in a new four-page leaflet, yours for the asking. Distributed by Ohio Crankshaft Co. Bulletin Oy-145.

## Centrifugal Casting

A new circular has been prepared by the Calorizing Co. describing their methods of centrifugal casting. Bulletin Dy-26.

## Modern Metallograph

The new Bausch & Lomb research metallographic equipment, which is arousing so much interest and favorable comment in the profession, is the subject of advance literature, recently issued. Bulletin Ba-35.

## Cutting Oils

The problems of machine tool lubrication engendered by the high speed production and close tolerances of modern industrial operations are discussed and progress in cutting oils during the past few years reviewed in a booklet by D. A. Stuart & Co. Bulletin Jy-118.

## Rustproofing

How the Detrex method of solvent degreasing provides the advantages of speed, economy, and satisfactory cleaning before all kinds of rustproofing and finishing operations is pointed out in a leaflet by Detroit Rex Products Co. Bulletin Dy-111.

## Spoilage Insurance

C. I. Hayes, Inc. has compiled a record of reports from over 300 users of their "Certain Curtain" controlled atmosphere furnaces showing how these furnaces have cut down spoilage in the heat treatment of tools. Bulletin Sx-15.

## Limitrol

An automatic shut-off instrument designed for use with or without controllers of any type to protect furnaces and furnace loads from excessive heating due to a weakness in control or failure in switching apparatus is described by Wheelco Instrument Co. Bulletin Ea-110.

## Steel Service

"Steel Service" is the title of a bulletin which gives valuable information on testing methods and pickling control charts. It is distributed by the Grasselli Chemicals Department of E. I. du Pont de Nemours & Co. Bulletin Aa-29.

## Cold Finished Bars

The importance of quality in cold finished steel bars is stressed in a small booklet by Union Drawn Steel Co., which describes the various types of carbon and alloy steels available in this form. Bulletin Ca-83.

## Hard Facing

An interesting and well-illustrated story is Lincoln Electric Co.'s 14-page booklet on hard facing for wear resistance. It also contains complete information on all types of Lincoln hard facing electrodes and gives the conditions for which each type is suited. Bulletin Ay-10.

## Metal Heating

Improvements in furnace economies, operating conditions and appearance, furnaces that will more satisfactorily meet old requirements or handle new processes, service that will help solve the most stubborn problems are offered and described by Mahr Mfg. Co. in Bulletin Ea-5.

## Alloy No. 10

A high temperature muffle furnace, the first of the Hevi Duty line of laboratory furnaces equipped with Alloy No. 10 allowing working temperatures to 2400° F., is described in Bulletin Jb-44.

## Flux

A short, informative bulletin covering the low melting temperature, rapid solvent action and wide temperature range of Handy Flux — which speeds up and improves brazing operations. Handy & Harman. Bulletin Oy-126.

## Furnace Control

How the Lindberg Control functions in balancing the rate of heating of a furnace or oven with the varying heat requirements is told in an attractive new bulletin issued by Lindberg Engineering Co. Bulletin Nv-66.

## Photoelectric Balance

C. J. Tagliabue Mfg. Co. has christened its newest, simplest and fastest recording potentiometer the "Celectray" from the photocell, electric current and light ray by means of which it operates. Described in Bulletin Ea-62.

## Air Weight Control

An illustrated booklet of sure-fire interest to the foundry trade has been issued by The Foxboro Co., explaining in detail the advantages of the "air weight controller" which is in use at many of America's leading foundries, named in the publication. Bulletin Ea-21.

## Oxidation

Designers confronted with oxidation problems connected with cracking coils, polymerization plants, superheaters, high pressure steam plants, air heating equipment and recuperators will welcome a folder by Timken Roller Bearing Co. containing data on oxidation at 1000, 1250 and 1500° F. Bulletin Ea-71.

## Calculator

A handy gadget is a sliding weight calculator which can compute weights per lineal inch of steel for 161,200 cross-section. Pocket-size, it contains tables for rounds, hexagons, octagons, squares and flats. Distributed by Heppenstall Co. Bulletin Ea-122.

## Brazing

Some of the jobs G-E electric furnace brazing is doing for manufacturers in the metal working industry, and the benefits obtained by its use are described in a reprint of a technical article by H. M. Webber, application engineer, General Electric Co. Bulletin Ea-60.

## Sheet Metal

One of the most modern of the current pieces of industrial literature dealing with sheet metal is Republic Steel Corp.'s "The Path to Sheet Metal Permanence," a 20-page booklet of useful information containing more than 60 interesting photographs. Bulletin Ea-8.

## Pneumatic Control

The free-vane principle of pneumatic control is recognized as a simple, reliable means requiring practically no power from the measuring unit to operate the control apparatus. A bulletin by Bristol Co. is devoted to Ampliset free-vane controllers. Bulletin Ea-87.

## Daily Reminder

Titanium Alloy Mfg. Co. publishes a small monthly memorandum book containing a thought-provoking quotation on the page for each day and supplemented by several pages of technical information on titanium. Bulletin Ea-90.

## Rails

"Brunorizing" is a new method of producing an improved steel rail for today's heavier and faster trains. A nicely printed and well illustrated 24-page booklet by United States Steel Corp. explains the process thoroughly. Bulletin Ea-79.

## Sheet Containers

The mechanical and thermal requirements peculiar to sheet carburizing boxes are explained in an illustrated folder by Driver-Harris Co. describing this particular type of equipment in detail. Bulletin Ea-19.

## Graphitic Corrosion

The peculiar form of disintegration occurring in cast iron which is known as graphitic corrosion is explained in a reprint of a technical article by Wesley, Copson and LaQue of International Nickel Co. Bulletin Ea-45.

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